N1K

DEPT. 105

B331 Mk II

AUTOBALANCE PRECISION BRIDGE

MAINTENANCE MANUAL

DEPT. 105

WAYNE KERR

MP MASTER
MA24502

DEPT. 105

AUTOBALANCE PRECISION BRIDGE

B331 Mk II

MAINTENANCE MANUAL

The Reference Number of this Publication is TP28/2

The Wayne K

Wilmot Breeden Electronics Limited
Durban Road, South Bersted, Bognor Regis, West Sussex, PO22 9RL
Telephone: Bognor Regis (02433) 25811 Telex: ~~86881~~ 86120
Incorporating ~~FERROGRAPH~~ • RENDAR • WAYNE KERR

Digitized by the Internet Archive
in 2025

https://archive.org/details/manualsplus_10857

CONTENTS PART I

Section		Page
1.	INTRODUCTION	7
2.	FUNCTIONAL DESCRIPTION	7
2. 1	Summary	7
2. 2	The Bridge	11
2. 2. 1	Preliminary Balance	11
2. 2. 2	Precise Balance	12
2. 3	Lead Eliminator	13
2. 4	Low Impedance Measurements	14
2. 5	Calibrate Facility	15
2. 6	Measurements Affected by Change of Frequency	15
3.	MECHANICAL DESCRIPTION	16
3. 1	General Construction	16
3. 2	Film Wiring	17
3. 3	Range Multiplier Lamps	17
4.	CIRCUIT DESCRIPTION	17
4. 1	Oscillator	17
4. 2	Bridge Nucleus	23
4. 2. 1	Lead Eliminator	24
4. 2. 2	Bridge Nucleus in Low Impedance Measurements	24
4. 3	Decade Switches and Bridge Standards	28
4. 3. 1	C and G Standards	31
4. 3. 2	C Decades	31
4. 3. 3	G Decades	32
4. 4	Bridge Trim and Vernier Controls	32
4. 5	Lead Eliminator Amplifier	33
4. 6	Feedback Amplifier	33
4. 7	Reset Switching	37
4. 8	Bandpass Filter	39
4. 9	90^{o} Phase Shifter	39
4. 10	Squarewave Generators	43
4. 11	Phase-Sensitive Detectors	43
4. 12	D. V. M. Outputs	43

Section		Page
4. 13	Indicator Switching	44
4. 13. 1	Digital Indicators	44
4. 13. 2	Operating Sequence Indicators	48
4. 13. 3	Decimal Point Indicators	48
4. 13. 4	Range Multiplier Indicators	50
4. 14	Power Supply Unit	50

CONTENTS PART II

Section		Page
5.	MAINTENANCE	55
5. 1	General	55
5. 2	Preliminary Measurement Check	55
5. 3	Push button and Vernier Check	57
5. 3. 1	Decade Push Buttons	57
5. 3. 2	Vernier Check	58
5. 4	Removal of the Rear Cover and Side Plates	58
5. 4. 1	To Release the Top Hinged Panel	58
5. 4. 2	To Release the Bottom Hinged Panel	58
5. 4. 3	Removal of the Nucleus Sub-Unit	59
5. 4. 4	Re-assembly	59
6.	SETTING-UP INSTRUCTIONS	60
6. 1	Test Equipment Required	60
6. 2	Checking 9V Supply	60
6. 3	Oscillator Frequency Adjustment	61
6. 4	Setting-up the Calibration Controls	61
6. 5	Feedback Amplifier	61
6. 6	Lead Eliminator Amplifier	63
6. 6. 1	Tuning Check	63
6. 6. 2	Gain Check	63
6. 7	Setting-up the Conductance Standards	64
6. 8	Elimination of Capacitance of the G Standard	66
6. 9	Setting-up the Capacitance Standard	66
6. 10	Setting-up the D. V. M. Outputs	67
6. 11	Nucleus Unit	68

Section		Page
6. 11. 1	Voltage and Phase Checks	68
6. 12	Replacement of Digital Indicator Tubes	70
6. 13	D. C. Voltages	71

ILLUSTRATIONS PART I and II

Fig 1	Basic Approach to Autobalance	8
Fig 2	B331 Block Schematic	9
Fig 3	Low Impedance Measurement	14
Fig 4a	Simplified Circuit of the Oscillator	19
Fig 4b	Oscillator Circuit	21
Fig 5	B331 Nucleus Circuit	25
Fig 6	Connections to Lead Eliminator on Ranges 2, 3 & 4	27
Fig 7	Connections to Unknown & Lead Eliminator (Range 1)	27
Fig 8	C & G Decade Switching & Standards Circuit	29
Fig 9	Lead Eliminator Amplifier Circuit	34
Fig 10	Feedback Amplifier	35
Fig 11	Reset Switching Circuit	38
Fig 12	Bandpass Filter and Phase Shifter Circuit	40
Fig 13	Squarewave Generator & Phase Sensitive Detector	41
Fig 14	D. V. M. Output Circuit	44
Fig 15	Digital Indicator Switching (Simplified)	45
Fig 16	Digital Indicator Switching	47
Fig 17	Sequence Indicator Switching	49
Fig 18	Decimal Point Indicators	49
Fig 19	Range Multiplier Indicators	51
Fig 20	Power Supply Circuit	53
Fig 21	General Internal View	56
Fig 22	Bandpass & 90^{o} Phase Shift Component Assembly	83
Fig 23	Inductor Board L3 Component Assembly	83
Fig 24	Feedback Amplifier Component Assembly	83
Fig 25	Squarewave Gen. and P. S. D. Component Assembly	84
Fig 26	Oscillator Component Assembly	84
Fig 27	C & G Decimal Point Indicator Component Assembly	85
Fig 28	'C' Sequence Indicator Component Assembly	85

		Page
Fig 29	'G' Sequence Indicator Component Assembly	85
Fig 30	Lead Eliminator Component Assembly	86
Fig 31	Standards Board Component Assembly	86
Fig 32	Reset Circuit Component Assembly	86
Fig 33	Power Supply Component Assembly	86

PART 1

1. INTRODUCTION

The physical description, specification and use of the B331 are dealt with in the Operating Instructions supplied with the instrument. This manual contains all the necessary information for those users who require a detailed knowledge of the circuits used, their operation and adjustment.

The book is divided into two parts, the first of which contains a complete technical description of the instrument together with a block diagram, all circuit diagrams and, where it is felt to be beneficial, simplified circuit diagrams of the various sub-assemblies.

The second part of the book deals with the setting-up and maintenance procedures necessary to keep the instrument in good order. Complete instructions are given for the adjustment of all preset controls and also for the replacement of the digital indicator tubes. In preparing these instructions, the use of any special test equipment has been avoided where possible. Finally, a complete list of electronic components is given.

The Autobalance Precision Bridge B331 uses the transformer ratio-arm principle. A complete analysis of this type of bridge is given in the Wayne Kerr Monograph No. 1, 'The Transformer Ratio-Arm Bridge'. An analysis of the self-balancing principles used in this instrument is given in Electronic Engineering Vol. 35, No. 430, December 1963, 'Self-Balancing Transformer Ratio-Arm Bridges'. Copies of the Monograph and reprints of the article are available on request.

2. FUNCTIONAL DESCRIPTION

2.1 SUMMARY

The B331 comprises a bridge nucleus, a 1592Hz oscillator*, a lead eliminator circuit, a feedback amplifier, a 90^{o} changer, a filter,

*NOTE A 1kHz oscillator can be fitted to order. Throughout this manual the standard frequency of 1592Hz is assumed. Differences in description or procedure arising from the use of the alternative frequency are noted where applicable. The components list gives values for both frequencies.

two phase-sensitive detectors - one for capacitance and one for conductance, a squarewave shaper, meter circuits, digital indicator units and a power supply unit. These circuits are connected as shown in the block diagram Fig. 2.

A standard voltage derived from a Wien bridge oscillator is applied via a voltage transformer in the nucleus to the component under test and the resulting current is fed via a current transformer also in the bridge nucleus to the feedback amplifier. A current from the feedback amplifier output is fed back to another winding on the current transformer in such a direction as to cancel the flux produced by the original current. Ideally, the system would indicate a true balance when these currents were exactly equal. However, since this would remove the feedback amplifier input signal, the balance indication falls short of this ideal condition by an amount which can be predetermined according to the required accuracy of the bridge. The approach to the ideal condition is governed only by the gain of the feedback amplifier, which can be made as large as necessary. This is shown diagrammatically in Fig. 1.

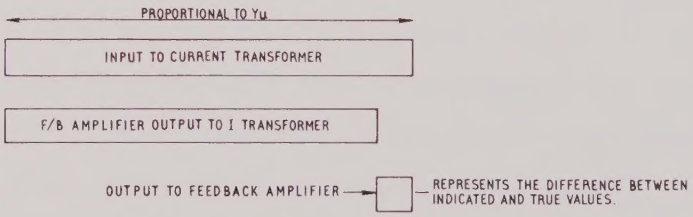

PROPORTIONAL TO Yu
INPUT TO CURRENT TRANSFORMER
F/B AMPLIFIER OUTPUT TO I TRANSFORMER
OUTPUT TO FEEDBACK AMPLIFIER
REPRESENTS THE DIFFERENCE BETWEEN INDICATED AND TRUE VALUES.

Fig.1 Basic Approach to Autobalance

It can be shown that the feedback amplifier output has components that are directly proportional to the capacitance and conductance of the component under test or, as the decades are brought into use, they are proportional to the difference between the decade setting and the value of the test component. The components of the output signal are then separated so as to operate the 'C' and 'G' meters simultaneously

2.2 THE BRIDGE

2.2.1 Preliminary Balance

This condition results immediately on connection of the unknown admittance Y_u (assuming correct range selection) and before the operation of any of the decades. Referring to Fig. 2 (and ignoring the lead eliminator for the moment), the voltage transformer T1 has a winding, tapped at several points, which produces a voltage E_u. This voltage is applied to one side of the unknown Y_u and causes a current I_u to flow through Y_u to a winding on the current transformer T7. This winding is also tapped at points equivalent to those on T1, the taps on both transformers being selected by means of the Range switch.

The flux in T7 causes an input signal to be fed to the feedback amplifier. A current proportional to the amplifier output E_f is fed back via the feedback resistor R_f to N_f turns on T7 wound in such a direction as to oppose the original flux. Since, at this stage in the measurement, the decades are not in use, the net flux in T7 is that produced by the difference between I_u and I_f (the feedback current) at the end of the preliminary balance, i. e., before the decades are introduced. The gain of the feedback amplifier is such that this flux can be assumed to be zero and therefore the feedback amplifier output is directly proportional to Y_u.

The feedback amplifier output has in-phase and quadrature components that are respectively proportional to the conductance and capacitance of the test component. The output signal is fed directly to the phase-sensitive detector associated with the conductance meter. The signal is also fed to a 90° phase shift amplifier whose closed loop gain is unity. The output from this amplifier is taken to the phase-sensitive detector associated with the capacitance meter. This arrangement gives an aperiodic indication of capacitance and thus does not depend on the oscillator frequency for accuracy.

Both detectors have a reference signal that is derived from the oscillator via a winding on the voltage transformer. Because the reference signal has a sinusoidal waveform it is not suitable to act as

reference signal has a sinusoidal waveform it is not suitable to act as a switching waveform, but is used instead to drive two squarewave generators shown in Fig. 13. The output from the squarewave generator is used to drive the bases of transistors which are used to gate the output of the feedback amplifier and the phase shifter. These gated output signals operate the C and G meters. Reversal of the meter polarity is achieved by phase reversal of the squarewave generator inputs by the polarity switches.

2.2.2 Precise Balance

The voltage transformer T1 has other multi-tapped windings that provide the voltages E_{sc} and E_{sg}, which are applied to the bridge standards. For simplicity, these are shown on Fig. 2 as single windings. The voltages E_{sc} and E_{sg}, which are applied to the C and G standards as soon as the first, or most significant C and G decades are operated, produce the currents I_{sc} and I_{sg}, respectively. Since the value of both E_{sc} and E_{sg} is selected - by means of the appropriate decade buttons - to correspond with the first digit of the initial meter indication, the resulting currents, when fed to windings on the current tranformer T7, partially balance the bridge to the extent represented by these first digits. The residual out-of-balance is then dealt with as before by the feedback amplifier and meter circuits. However, the meters would not give a very useful indication unless a corresponding increase were made in the detector sensitivity. By making this increase in sensitivity equal to ten times, the new meter indications give the second and third significant figures. Similarly, when the second order decades are operated to transfer the first digits of the new meter indications to the second order indicators, a simultaneous ten-times increase in detector sensitivity again takes place so that the meters then indicate the third and fourth significant figures. When the process is repeated with the third order decades, a 5-figure readout (or 6-figure readout at full range capability) is attained at the full 0.01% accuracy of the system.

The G 'standards' windings on T7 has a centre-tap, which is connected to neutral; the current I_{sg} is fed to one or the other of its respective outers via the G polarity switch so that the flux change in T7 can be either additive or subtractive according to the required polarity. The C 'standards' winding on T7 is untapped, therefore, to change the polarity of this winding, two cross-connected switches are incorporated enabling the ground connection to be transferred from one side of the winding to the other. Connections from the G windings on both voltage and current transformers are brought out to rear panel sockets E_{+10} and I_{-12} for the connection of external standards. The various uses of these sockets are explained in the Operating Instructions handbook.

2.3 LEAD ELIMINATOR

On ranges 2, 3 and 4, the internal impedance (i.e. the impedance of the transformer windings, connecting leads and switch contacts) would be sufficiently large to make a significant difference between the true and indicated values of the unknown admittance were it not for the presence of the 'lead eliminator'. This error is caused by the passage of the current drawn from the voltage transformer by the unknown through the leads and switches etc. The lead eliminator circuit senses the voltage actually applied to the unknown and compares this with a reference voltage E_{ref}; the difference is then fed to a feedback amplifier so as to derive a correcting voltage, which is added in series (via T3) with the main voltage winding on T1. The reference voltage is obtained from a winding on the voltage transformer that is similar to the E_u winding but, because the reference winding is at all times unloaded, its voltage remains accurate. The lead eliminator connections are shown in Fig. 6 and 7.

As with any feedback system, the correction falls short of perfection by the amount necessary to drive it, and is therefore a function of the gain of the lead eliminator amplifier. In practice, the internal impedance is reduced by approximately one-hundred times.

2.4 LOW IMPEDANCE MEASUREMENTS

When it is required to measure impedance values below 10Ω, the method of measurement described in the previous paragraphs becomes impracticable owing to the uncertainty of lead and contact resistances. For the precise measurement of such low impedances a different technique is adopted.

In the bridge arrangement as previously considered, a standard voltage is applied to the unknown and the resulting current is compared with that in a standard impedance. For low values of unknown impedance, i.e. when the Range switch is set to 1 (Low Impedance), the bridge configuration is re-arranged so that Y_u is the shunt element in a T-network (see Fig. 3). If the series elements are made sufficiently large compared with the unknown, the source side of the bridge can be considered as a constant current generator while the detector side functions as a voltmeter. This technique is analysed in Wayne Kerr Monograph No. 1.

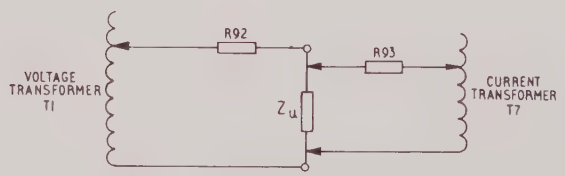


Fig.3 Low Impedance Measurement

In practice, the series elements (R92 and R93) are made 100 times greater than the range maximum. This factor would normally give rise to a systematic error of 2% (explained in Section 4. 2. 2) but the lead eliminator is re-arranged to reduce this error to negligible proportions so that the maximum accuracy on this range becomes 0.2%, this being the combined tolerance of R92 and R93. This re-arrangement is made possible because the lead eliminator would otherwise be redundant on Range 1 since the system of measurement requires a four-terminal connection.

2.5 CALIBRATE FACILITY

The internal standards of the instrument are used to calibrate the bridge meter circuits before making actual measurements. In normal use, current from the 'standard' side of the bridge is fed to the current transformer to balance the current (or a portion of it) from the 'unknown'side. If current from the 'standard' side is fed to the transformer in the absence of any 'unknown' current (as, for instance, during calibration) the meter circuits would indicate in a negative direction. This is overcome by arranging for the Facility switch, when set to Calibrate, to reverse the phase of the reference voltage fed from the voltage transformer to the squarewave generator. The internal standards, in conjunction with the decade switches, can then be used to set up a standard indication on the C and G meters, the main feedback network being then adjusted to correct the meter indications as necessary.

2.6 MEASUREMENTS AFFECTED BY CHANGE OF FREQUENCY

Since the bridge uses a capacitance standard for the measurement of admittance, any measurements on inductors (made on the normal ranges) must be frequency dependent. On the Low Impedance range (Range 1), owing to the effective inversion of the method of measurement (see Section 2.4) whereby the bridge measures equivalent series components instead of equivalent parallel components, it is the capacitance measurements that are frequency dependent.

The bridge standards and the transformers are so arranged that, at the design frequency, the range coverage follows logically to the next decade when changing from Range 2 to Range 1, that is, from a parallel to a series type of measurement. At other frequencies, however, the range coverage is not sequential owing to the presence of the term ω ($=2\pi f$) in the denominator of the expression for L on Ranges 2 to 8 and C on Range 1. The effect of this is to cause a range overlap as the frequency increases and a gap as the frequency decreases. The extent of the gap at different frequencies is shown by means of a graph in the 'Operating Instructions', which also gives alternative methods for use under these conditions.

3. MECHANICAL DESCRIPTION

3.1 GENERAL CONSTRUCTION

The various sub-units of the instruments are disposed round five sides of the assembly, including the front panel. The two side castings of the assembly are secured to the front panel but the top and bottom trays are hinged. Thus, by opening these panels, the interior of the instrument is completely exposed for maintenance purposes.

The bridge nucleus comprises four sub-units and is mounted on a plate which is fitted to the bottom tray. These sub-units contain six out of the ten transformers in the instrument; these are T1, T2, T3, T5, T6 and T7. Also located in the nucleus unit are nine sections of the range switch S2; S2/1 and S2/6 each comprise two wafers in order to accommodate the width of some of the tape conductors from the voltage and current transformers. Two other sections of S2 (S2/18 and S2/19) are associated with the lead eliminator circuit. The part of the Range switch that is located in the nucleus is directly coupled to the main part of S2 by a sleeve coupling. The end of the shaft that protrudes through the rear of the nucleus operates the power supply on/off switch.

There are six main printed circuit boards as follows:

(a) The 90^{o} phase shifter and filter; this is the largest board and is mounted on the top hinged panel.

(b) The feedback amplifier; this circuit is housed on two circuit boards situated below the 90^{o} phase shifter and filter. Beneath the metal screen is the tunable section of the feedback amplifier.

(c) The C and G phase sensitive detectors and squarewave generators; the two phase sensitive detectors are identical and are mounted on one board positioned below the SET FSD controls on the top tray.

(d) The oscillator; this p.c. board is in a metal box and is situated immediately behind the G front panel meter.

(e) The lead eliminator amplifier, situated between the C and G range multiplier indicators.

(f) The power supply p.c. board; this is situated within a metal box which is fitted on the right-hand side of the instrument, viewed from the rear.

The smaller box immediately below houses the mains transformer. There are also a number of minor p.c. boards that carry the decade indicator tubes and some of their associated components.

3.2 FILM WIRING

The greater part of the circuits associated with the decade switches are connected by means of film wiring. This consists of thin film copper tape (similar to that on normal printed circuit boards) sandwiched between two sheets of a flexible plastic material.

3.3 RANGE MULTIPLIER LAMPS

The capacitance and conductance range multiplier indicators are two similar assemblies each of which comprises twelve indicator lamps and an optical system. The light from the selected lamp passes through a plastic condensing lens in front of which is a mask carrying the twelve symbols. A light trap prevents stray light from passing through any but the selected image. The light beam then passes through a projection lens and a further light trap to the Perspex viewing screen. Apart from the lamp block, which can be withdrawn for replacement of the lamps, the unit is a sealed assembly. The lamp block is secured by two captive 6BA screws, one at each side.

4. CIRCUIT DESCRIPTION

4.1 OSCILLATOR

A simplified circuit diagram of the oscillator is given in Fig. 4a and the complete circuit diagram in Fig. 4b. The circuit is essentially that of a Wien Bridge oscillator in which the four arms of the bridge network are R1/C1, R2/C2, thermistor TH1 and silistor R9. Overall feedback is taken from the feedback winding on T1 and the values of

the Wien Bridge network components are such that the feedback is in phase at 1592Hz (or 1000Hz if appropriate) so causing the circuit to oscillate at that frequency.

Thermistor TH1 counteracts variation in the oscillator output should changes occur in the load or supply voltage. However, since TH1 cannot differentiate between an incipient change in output level and a change in ambient temperature, the temperature-sensitive element ('Silistor') R9 is included in the Wien Bridge network, to compensate for ambient temperature changes.

Transistors VT1 and VT2, which form the high gain amplifier, are connected as a d.c. feedback pair to give improved stability over the operating temperature range. Transistors VT3 and VT4 are a long-tailed pair output stage. The emitter circuit of the long-tailed pair incorporates a constant current generator, VT26.

Initially, the collector of VT1 and the base of VT2 are at the supply potential and VT2 conducts. The potential at the emitter of VT2 is divided by the potential divider R10/R11. The voltage at the junction of R10/R11 is fed back via R2 to the base of VT1, so causing VT1 to conduct. VT2 base and, hence, emitter potential is reduced and this, in turn, reduces the potential at VT1 base. Negative feedback, moderated by R6/C5, is applied to VT1 collector circuit by returning R4 to the collector of VT4.

The system is stabilised at a level determined by the feedback tapping point on VT2 emitter. The d.c. feedback to VT1 base greatly reduces the tendency of the base/emitter potential to drift with temperature variation; this ensures that the operating point for VT2 collector is reasonably constant. Capacitors C6/C7 prevent feedback at the operating frequency.

The output from the d.c. feedback pair is taken from the collector of VT2 via the phase-correcting coupling network R14, C38, C39 to the oscillator output stage. This comprises the long-tailed pair VT3 and VT4 in whose collector circuit is the centre-tapped primary winding of the voltage transformer T1. The transistor VT26 in the emitter circuit of VT3/VT4 gives the effect of a high impedance without the necessity

for a high voltage h.t. line.

When the instrument is used with an external source and detector, the Wien Bridge network is disconnected from the base of VT1 by means of switch S1/1. The external signal then passes via SK20, PL8(C), C62, PL8(D), S1/1, and PL8(H) to the base of VT1. Transistors VT1 to VT4 and VT26 amplify the signal as described in the previous paragraphs. When switch S1 is set for operation from an external source, S1/2 connects R155 in place of thermistor TH1 in the feedback path, thus preventing damage to the thermistor should an excessive signal be applied to SK20. In normal use, the oscillator output is such as to produce a peak-to-peak voltage in T1 of approximately 100mV per turn; when an external source is used, the input level should be adjusted so as to approximate this condition. Potentiometer RV18 and C84 give a small degree of frequency adjustment.

4.2 BRIDGE NUCLEUS

The contents of the Bridge nucleus were given in Section 3.1, the circuit diagram is given in Fig. 5. From this it will be seen that the tappings on the range winding of T1 are arranged in multiplies of 3 and 10 while those on the range winding of T7 are in multiples of 4 and 12. This arrangement keeps the turns on each side of the bridge more nearly balanced than would be the case if the windings were tapped in orders of ten - when the E and I windings would be either equal or ten times different on successive ranges.

The maximum number of turns on the E and I range windings (T1 and T7) compatible with the attendant losses and required accuracy are 300 and 400 respectively. This criterion makes it necessary to use the auto transformers T2 and T6 to obtain the range tappings for Range 2 and 3 since it is impossible to produce fractional turns. Thus the tappings on T2 are equivalent to tappings of 1 turn and 0.3 turn on T1 while those on T6 are equivalent to tappings of 1.2 turns and 0.4 turn on T7.

The voltage from T1 (or T2 on ranges 2, 3 and 4) is fed via the switch S2/1 and the inner screen of the triax socket SKT2(E) to the component under test. Current is then fed via the inner screen of triax socket SKT3(I) and switch S2/6 to the current transformer T7 (T6 on ranges 2, 3 and 4). The inner screen of the triax connectors is used for the signal circuit in preference to the centre core because it is a heavier conductor and will therefore cause a smaller volt drop owing to the load current than would the centre core. On the other hand, the lead eliminator circuit takes an insignificant current and can therefore use the centre core of the triax connectors with impunity.

4.2.1 Lead Eliminator

The reference voltage E_{ref} referred to in Section 2.3 is taken from a three-turn winding on T1 and applied to the auto transformer T5. Tranformers T5 and T2 are identical and so, if there were no losses, equal potentials would be applied at point (a) in Fig. 6 and the points (b) and (c) would be equi-potential. However, the current I_u causes a volt drop in the connections between T2 and Y_u so that the potential at (b) becomes lower than that at (c). This difference is fed to the lead eliminator amplifier (see Section 4.5) whose output is applied to transformer T3; the secondary winding of T3 is connected in series with the lower end of T2. Thus the lead eliminator output raises the potential level of T2 until the points (b) and (c) are in fact at equal potentials (equal, that is to say, within the limits of the system - see Section 2.3).

4.2.2 Bridge Nucleus in Low Impedance Measurements

It has been explained in Section 2.4 why the configuration of the Bridge is changed when measuring low impedances and this was illustrated in simple form in Fig. 3. The diagram in Fig. 7 shows in detail how the change is accomplished. Consider for a moment the simple circuit of Fig. 3. Though it was stated in Section 2.4 that the source side of the Bridge can be considered as a constant current generator, it will be appreciated that this is strictly so only if the impedance of Y_u is zero; similarly, the loading on the detector is negligible only

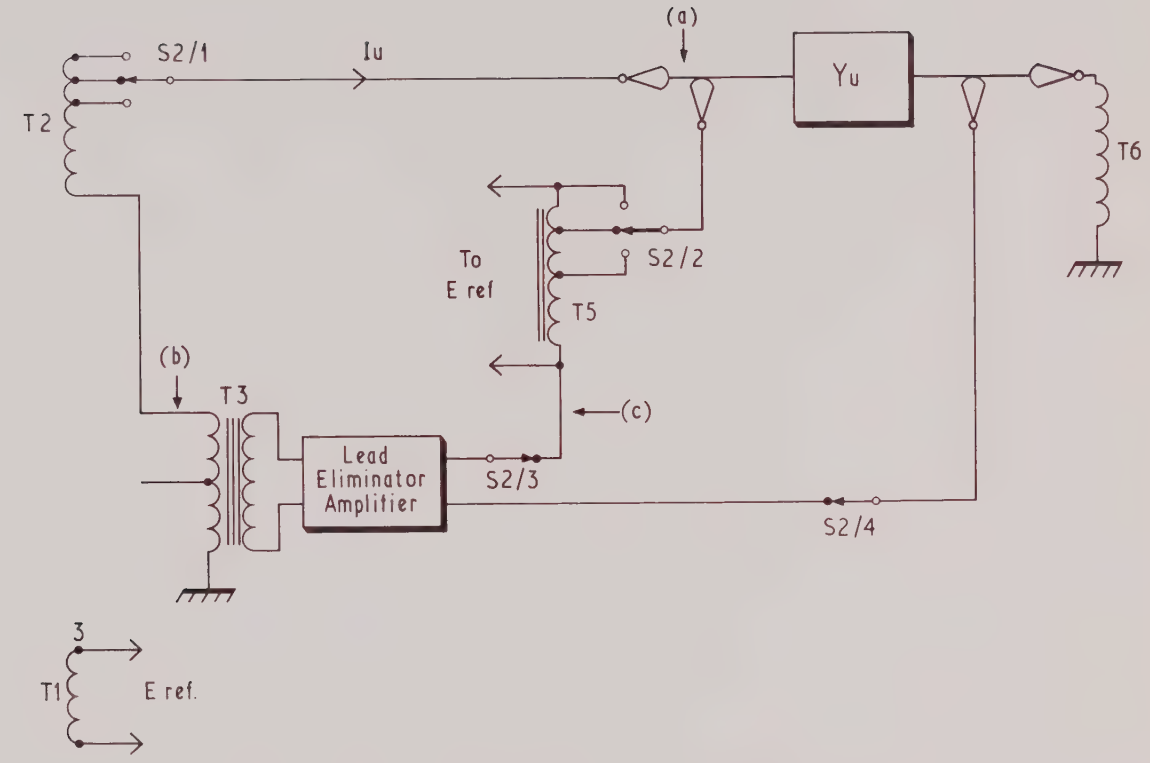


Fig.6 Connections to Lead Eliminator on Ranges 2,3 & 4

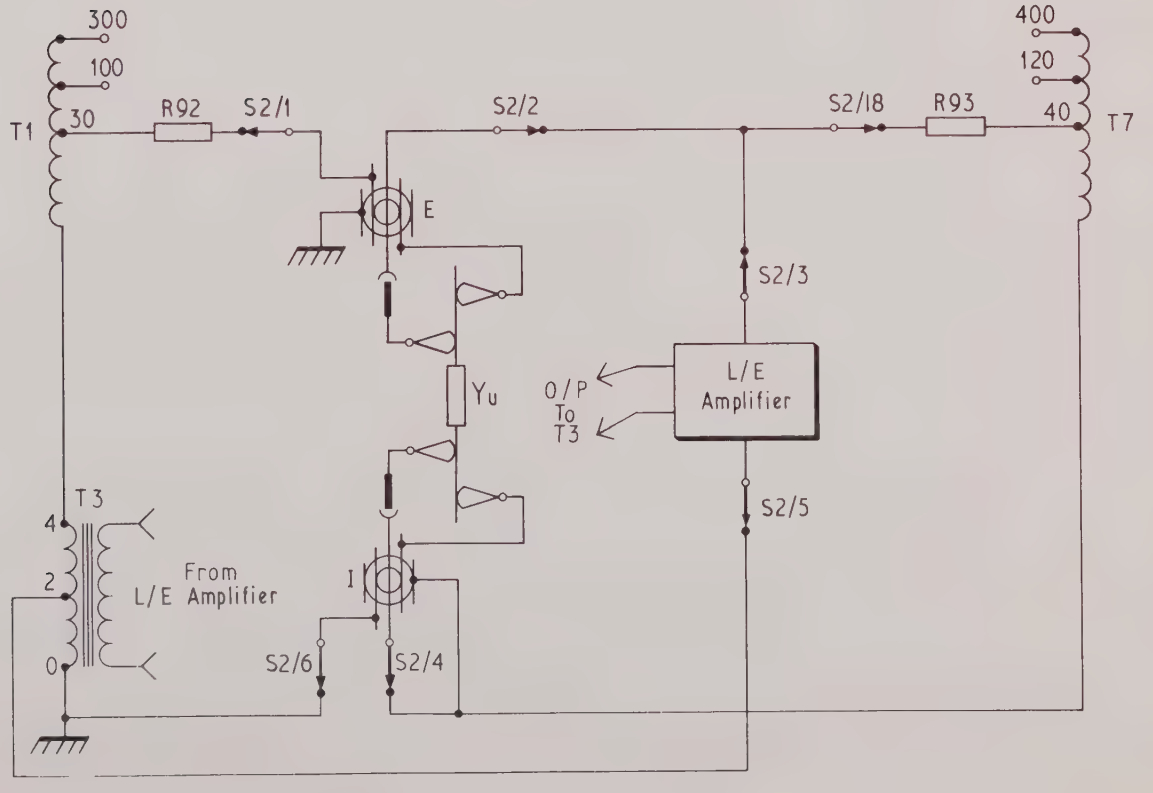


Fig.7 Connections to Unknown and Lead Eliminator on Range 1

when Y_u is small compared with the detector input impedance. Since the value of R92 is 1kΩ and the impedance of Y_u can vary between 0 and 10Ω, the maximum error would be 1%; also, since the input impedance of the detector is 1kΩ (R93), a further 1% error occurs when the impedance of Y_u is 10Ω.

On the Low Impedance range, the function of the Lead Eliminator is switched (see Fig. 7) so as to detect the voltage across the unknown and to increase the source voltage (as on other ranges) but, instead of adjusting the voltage across the unknown to be equal to a reference voltage, it adjusts the source voltage to produce:

(a) the correct nominal constant current in the unknown.

(b) an additional current to offset the detector loading error.

Considering first (a) only, the lead eliminator amplifier would require a gain of unity because then, whatever the voltage across the unknown, on being applied to the lead eliminator the source voltage would be raised by an identical amount to overcome this loss, thus closely maintaining the constant current. In fact, the impedance of the voltage detector is the same as that of the current generator and so the effective loss is doubled, therefore the gain required from the lead eliminator amplifier is two; this then produces the additional current (b). The amplifier gain of two is achieved by applying voltage feedback to the input-low terminal (the input being differential in nature) from a centre-tap on the lead eliminator output transformer secondary.

4.3 DECADE SWITCHES AND BRIDGE STANDARDS

The decade switches are associated with the following circuits.

(a) The C and G decade windings on the voltage transformer T1.

(b) The decade indicator tubes.

(c) The operating sequence lamps.

The following paragraphs deal with item (a) above and explain the operation of the decade switches in conjunction with the C and G standards. The circuit diagram for this section of the instrument is given in Fig. 8.

4.3.1 C and G Standards

Before explaining the decade switching in detail, a few words about the standards themselves will explain the basic difference between the C and G systems. This difference is that whereas in the case of C there is one standard and three decade windings, in the case of G there are three standards and one decade winding. The reason for this is that resistors suitable in size, accuracy and stability for use as conductance standards are readily available, but this is not so with capacitors. In this application, long-term stability and low temperature coefficient are more important than absolute value. The capacitance standard used in the B331 has a stability that is measured in terms of only a few parts per million.

NOTE: THE STANDARD CAPACITOR C9 IS FILLED WITH DRY NITROGEN AND THEREFORE MUST NOT BE OPENED.

4.3.2 C Decades

The voltage transformer T1 has one C decade winding, which consists of 300 turns tapped at every 30 turns; the second winding is an auto transformer having 200 turns and is tapped at every 20 turns. The voltage from 20 turns of this auto winding is fed to another winding on the same auto transformer T4, which is 20 turns tapped every 2 turns. The first order decade switch connects the second order winding (T4) between any adjacent pair of taps on the first order winding (T1). Similarly, the second order switch connects T4 between any adjacent pair of taps on its second order winding. Finally, the third order switch selects the appropriate tap on T4 and feeds the voltage at that point to the C standard , C9. This process is made clear in the simplified inset diagram in Fig. 8. Note that there are eleven taps on the first and second order decade windings; this allows a '10' to be included in the decade switches (the switches that control the indicator tubes are connected so as to provide a 'carry' facility). Thus the voltage applied to C9 can be set to four significant figures. Current from C9 is fed via the C polarity reversal switches PMC1 and PMC5 to a 160 turn winding on T7.

4.3.3 G Decades

The G standards are fed from a ten turn winding on T1 via a single 100 turn winding T9 tapped every ten turns. A voltage selected from this winding by the first order G decade switch is fed to R22; a voltage selected from the same winding by the second order switch is fed to R23 (ten-times the value of R22); finally, and again from the same winding, the third order decade switch selects and feeds a voltage to R24 (one-hundred times the value of R22). The currents from these three standards are added together and fed via the G polarity switch PMG1 to a +12 or -12 winding on T7. This also is shown in a simplified form in the inset to Fig. 8. Trimmer capacitor C12, in parallel with R22, gives first order phase correction. Second order phase errors are corrected by C85 in conjunction with the T-network R312, C210 and R313. The effect is to make the network appear inductive thus neutralising the capacitive effect of the standard. Third order phase errors are insignificant.

4.4 BRIDGE TRIM AND VERNIER CONTROLS

A two turn centre-tapped winding on T1 is coupled to RV2 and RV3, the G and C trim controls respectively enabling plus and minus one turn of voltage adjustment with the Trim potentiometers. The C and G trim currents are both fed to the G winding of T7 via C10 and R21 respectively.

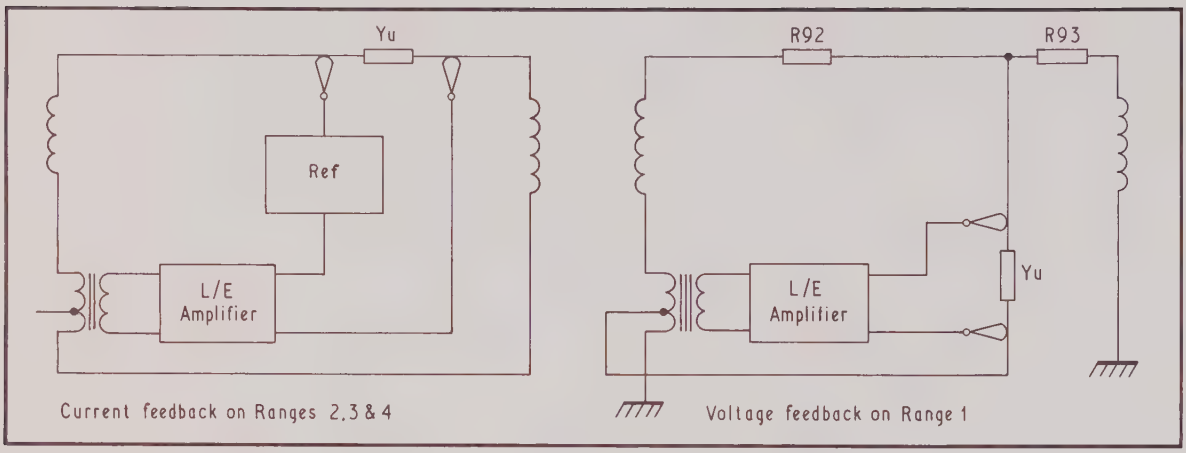
The one-turn voltage from one side of the two-turn tapped winding on T1 is also fed to RV4 (Vernier G) and RV5 (Vernier C). RV4 and RV5 controls are returned to ground and so each provides a variable offset voltage whose maximum is equivalent to full-scale deflection of the meters at maximum sensitivity. The C offset voltage is fed via C11, and the G offset voltage via R25, to T7. To compensate for tolerance in the value of C11, RV15 is added in series with RV5. Such adjustment is not necessary in the case of RV4 because R25 is a close-tolerance component.

4.5 LEAD ELIMINATOR AMPLIFIER

The circuit diagram of the Lead Eliminator Amplifier is given in Fig. 9. The difference between the output from T5 and the potential across Y_u (see Fig. 6) is fed as a differential input between the base and emitter of VT22, whose collector load is the tuned circuit L4 and C48; this is tuned to the operating frequency of the bridge. Transistors VT23 and VT24 form a compound amplifying stage with feedback in the ratio of the impedance of the networks R87/R88/C51 and R89. D.C. feedback for the first two stages is obtained by connecting VT22 base bias R81/R85 to the emitter of VT23. The output of the amplifier is taken via C52 and the switches S2/19 and S2/8 to the primary of T3. Switches S2/19 and S2/8 reverse the phase of T3 primary on Range 1 (Low Impedance) as required by the fundamental difference in the application of the system for low impedance measurements (see inset on Fig. 9). The primary winding of T3 is short-circuited on Ranges 5 to 8 so as to avoid unwanted effects when the lead eliminator is not in use. Fitted to this amplifier is a switch annotated IN/OUT. It must be left at the IN position unless specified otherwise under certain servicing conditions.

4.6 FEEDBACK AMPLIFIER

The Feedback Amplifier comprises a tuned preamplifier VT8/VT9 and a two-stage switched gain output amplifier VT29, VT10/VT11, VT12. The circuit diagram is given in Fig. 10. The output from the current transformer T7 is fed via C14 and R26 to the base of VT8, which with VT9 forms a d.c. feedback pair. The a.c. path for the emitter of VT9 is via R32 and C19; this, in conjunction with the feedback resistor R27, gives the stage an alternating current gain of 50dB. The output current from VT9 drives the tuned circuit L3/C15 - tuned to the bridge frequency - so transforming the current into a voltage. The overall voltage gain of the stage is 86dB. The diodes MR20, MR21 in the tuned circuit have no effect under normal conditions of operation but, under overload conditions, they restrict the output from VT9 and prevent the system from becoming paralysed.



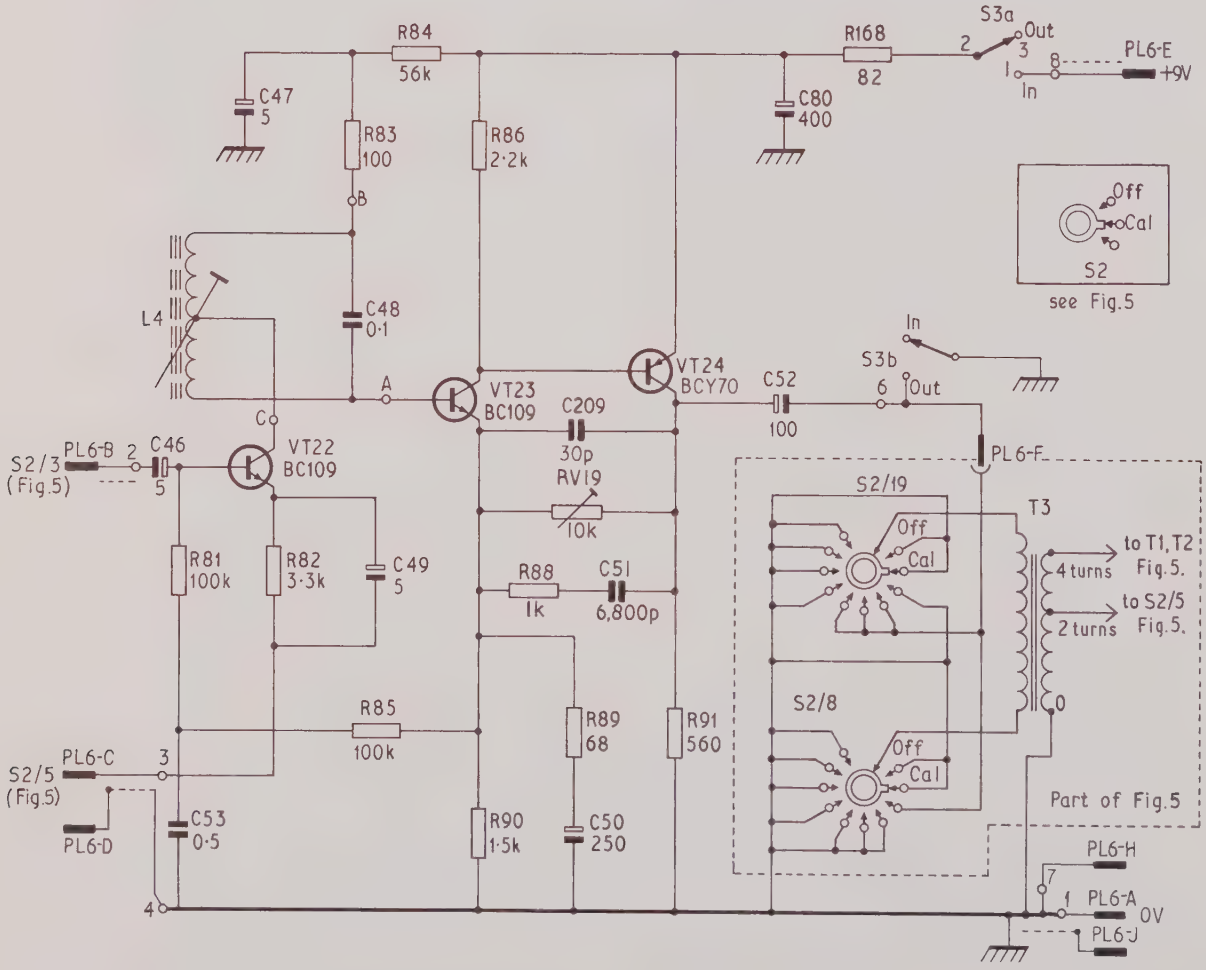


Fig.9 Lead Eliminator Amplifier Circuit

B331MKII
DI3908B

The output from VT9 is fed via C17 and the buffer stage VT29 to the base of the variable gain stage VT10. The network R34/C20 in parallel with the collector load of VT10 controls the high frequency response of the amplifier; the networks in the collector circuit of VT11 have a similar function, the overall effect being to produce a fall in open-loop gain, not exceeding 30dB per decade. The emitter load of VT10 is in three sections R36, R37 and R38; the decoupling capacitor C45 is switched by the Reset circuits (see Fig. 11) so as to be either open-circuit or to decouple R38 or R37 and R38 together.

Transistor VT11 is a straightforward driver stage feeding the emitter follower output stage VT12. There are two d.c. feedback paths, one from VT12 emitter back to VT10 emitter (this is also the a.c. feedback path) and the other from VT11 emitter back to VT29 base. This arrangement gives a very high degree of d.c. stability. The output from the emitter of VT12 is fed via C26 to the feedback transformer T8; this has a winding of 1000 turns and is tapped at 100 turns, 10 turns and 1 turn. Selection of the 100-turn tap and the connection of C45 to the junction of R37/R38 is synchronous with the operation of the first order decade. Operation of the second order decade connects C45 to the junction of R36/R37 and selects the 10-turn tap on T8. Finally, operation of the third order decade selects the 1-turn tap on T8, leaving the connection of C45 unchanged. This arrangement preserves the stability of the system by keeping the loop gain within reasonable limits.

4.7 RESET SWITCHING

The reset switching, shown in Fig. 11, performs two functions, namely, it switches the decoupling capacitor C45 to the appropriate point on VT10 emitter circuit and it switches the feedback network between the appropriate tap on feedback transformer T8 and the feedback winding on current transformer T7. The main feedback resistance (R_f in Fig. 2) is the sum of resistors R94, R95, RV14 and RV16; the remaining components in the network, RV13, R104, R105, C56 and C57, correct the feedback phase angle. The potentiometers RV13 and RV16 are adjusted during the calibration check prior to actual measurements.

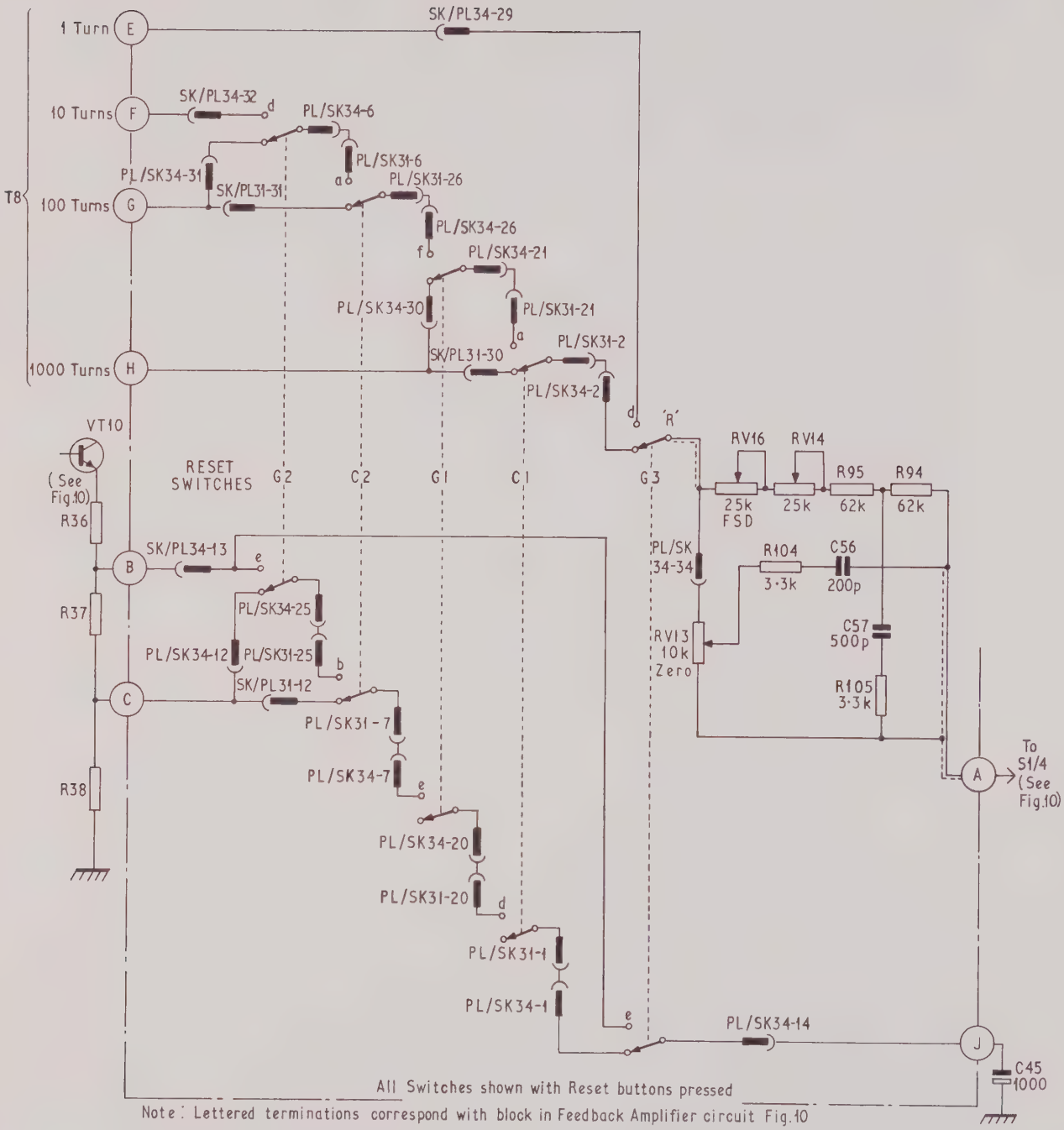


Fig.11 Reset Switching Circuit

B331 MKII
D13901 D

RV14 is used to adjust the range of RV16. It will be seen from Fig. 11 that the third order G decade overrides all other decades; thus when the third order G button 1 is pressed during the Calibrate procedure (see Operating Instructions) the feedback amplifier assumes its most sensitive condition and the 'standard' current selected should produce f. s. d. on the G meter. Potentiometer RV16 adjusts the feedback resistance to achieve this condition. Under these conditions, with no 'unknown' current and no capacitive 'standard' current, the output from the C p-s detector will be zero if the feedback amplifier phase is correct; RV13 is adjusted until it is (i.e. until the C meter indication is zero).

4.8 BANDPASS FILTER

Before passing to the phase-sensitive detectors, the feedback amplifier output is fed to the bandpass filter circuit comprising VT27, VT28 and their associated circuits; these are given in Fig. 12. The filter response is centred on the bridge operation frequency. In the measurement of inductance it is particularly important that the signal should be free from harmonics; this is because the unknown and standard arms of the bridge react differently and would thus introduce serious errors. The chosen oscillator circuit gives a good sinusoidal output but the filter is included to remove residual harmonic frequencies. It will be seen from Fig. 12 that the circuit associated with VT27 constitutes a high-pass section whilst that of VT28 constitutes a low-pass section.

4.9 90^{o} PHASE SHIFTER

Since the capacitance component of the output from the feedback amplifier is in quadrature with the detector reference signal, the output must be fed through a 90^{o} phase shift circuit before it can operate the C meter circuit. The circuit of the 90^{o} phase shifter is given in Fig. 12.

The output from the bandpass filter is fed via the preset phase correcting network RV7 and C27 to an operational amplifier comprising

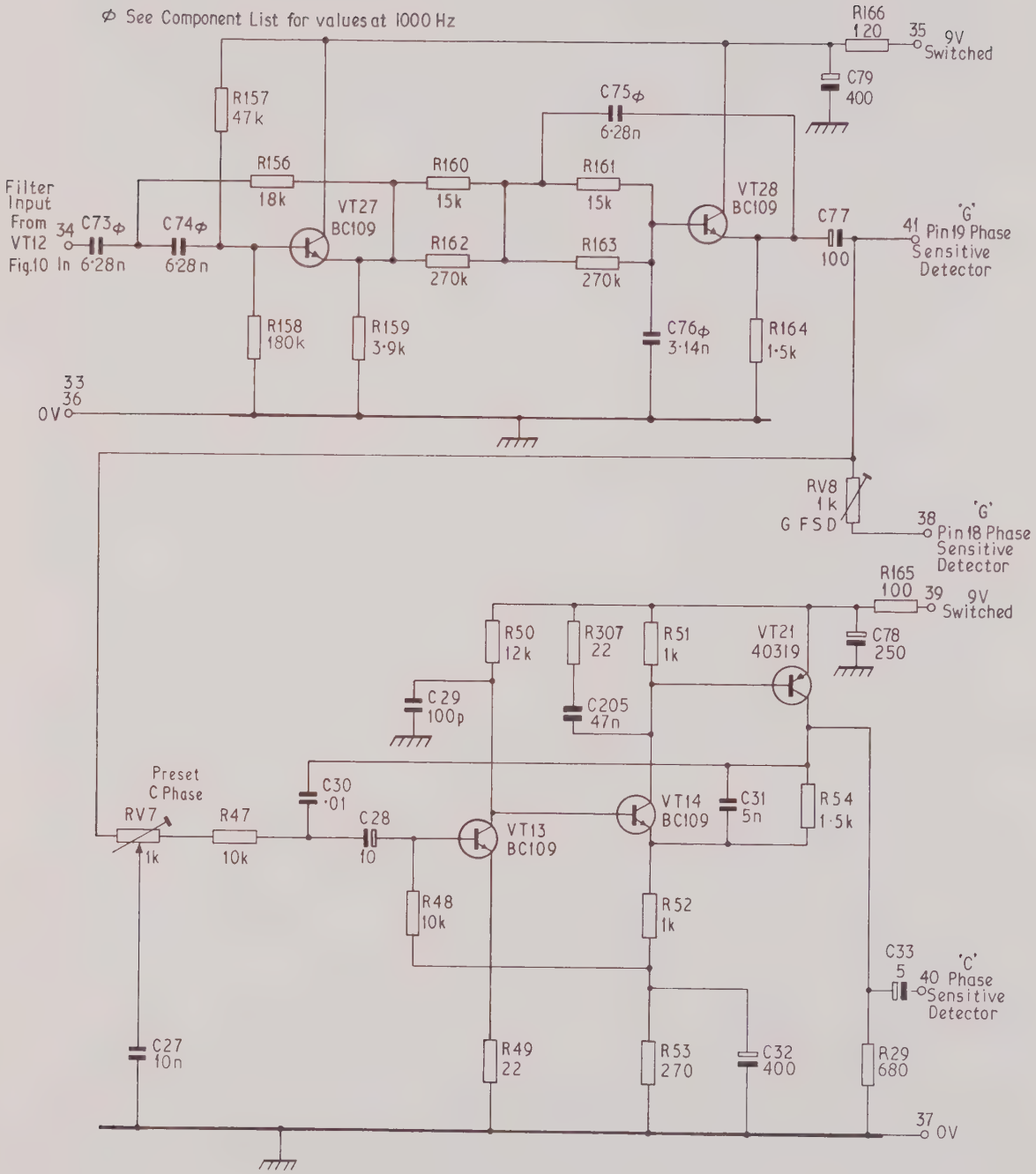


Fig.12 Band Pass Filter and Phase Shifter Circuit

B331 MkII
D13903

VT13, VT14 and VT21. Potentiometer RV7 allows the phase shift to be set exactly to 90°. The gain of the system is determined chiefly by the input resistor R47 and the feedback capacitor C30. The capacitors C29 and C31 improve the stability of the circuit.

4.10 SQUAREWAVE GENERATORS

The purpose of the Squarewave Generators IC1 and IC2, whose circuits are given in Fig. 13, are to provide a fast switching waveform for the gating transistors VT17 and VT18 which control the input to the C and G meters.

The input to both squarewave generators is fed via the appropriate polarity switches so that the phase of the reference signal from the oscillator can be reversed when required.

4.11 PHASE SENSITIVE DETECTORS

Two meters with appropriate series multipliers are connected across the output of the filter and the phase shifter (Fig. 12) for G and C measurements respectively. By gating the meter inputs with a squarewave reference signal, the meter circuits are made phase sensitive. The gate drive waveform is derived from the oscillator via the voltage transformer T1 and the squarewave generator and so it is in synchronism with the detector input. Meter damping is provided by the capacitors C207 and C208.

4.12 DVM OUTPUTS

The C and G phase-sensitive detectors each incorporate a circuit whose purpose is to provide a voltage output with respect to ground (chassis) that is proportional to the meter indication and which can be used to operate a digital voltmeter or recorder. For ease of understanding, the DVM output components associated with the G detector are shown separately in the scrap circuit Fig. 14. From this diagram, the corresponding components for the C detector can be readily identified.

The circuitry, comprising R76, C59, C81, RV9 and R77, associated with the detectors is necessary to provide additional smoothing to the

detector signal for the external digital voltmeter and to provide level adjustment at the C and G -DVM outputs. The C or G SET FSD controls are adjusted to give an output of 100mV into 100kΩ with the appropriate panel meter reading full scale.

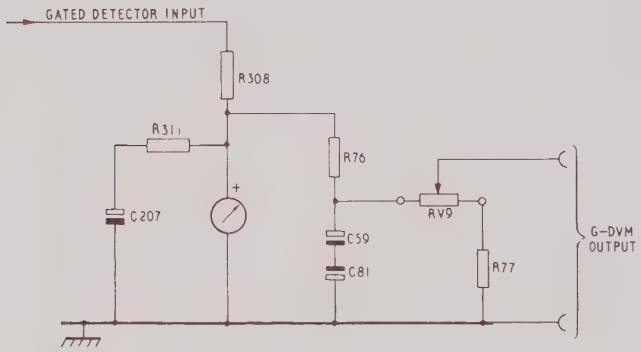


Fig. 14 D V M Output Circuit

4. 13 INDICATOR SWITCHING

4.13.1 Digital Indicators

The illuminated display of the values of capacitance and conductance is given by means of digital display tubes, four tubes and three decimal point indicators for each. The display tubes are energized by means of the push-button decade switches, each decade comprising eleven numeral buttons (0 - 10 inclusive) and a reset button. The anode of each display tube is connected via a load resistor to a 250V supply and the operation of any decade button between 0 and 9 connects the appropriate cathode to ground (see Fig. 16). The circuit is so arranged that when button 10 on a lower order decade is operated, the next higher order display tube indicates a numeral which is greater by one than the operated button for that tube; at the same time, the lower display tube shows 0 (e.g. if the first order button 4 and second order button 10 are operated, the display tubes indicate 5.0). This system operates through all three decades so that if, for example the display indicates 5.99 and the third order button 10 is then pressed, the display will indicate 6.00.

For ease of understanding, the simplified digital switching diagram

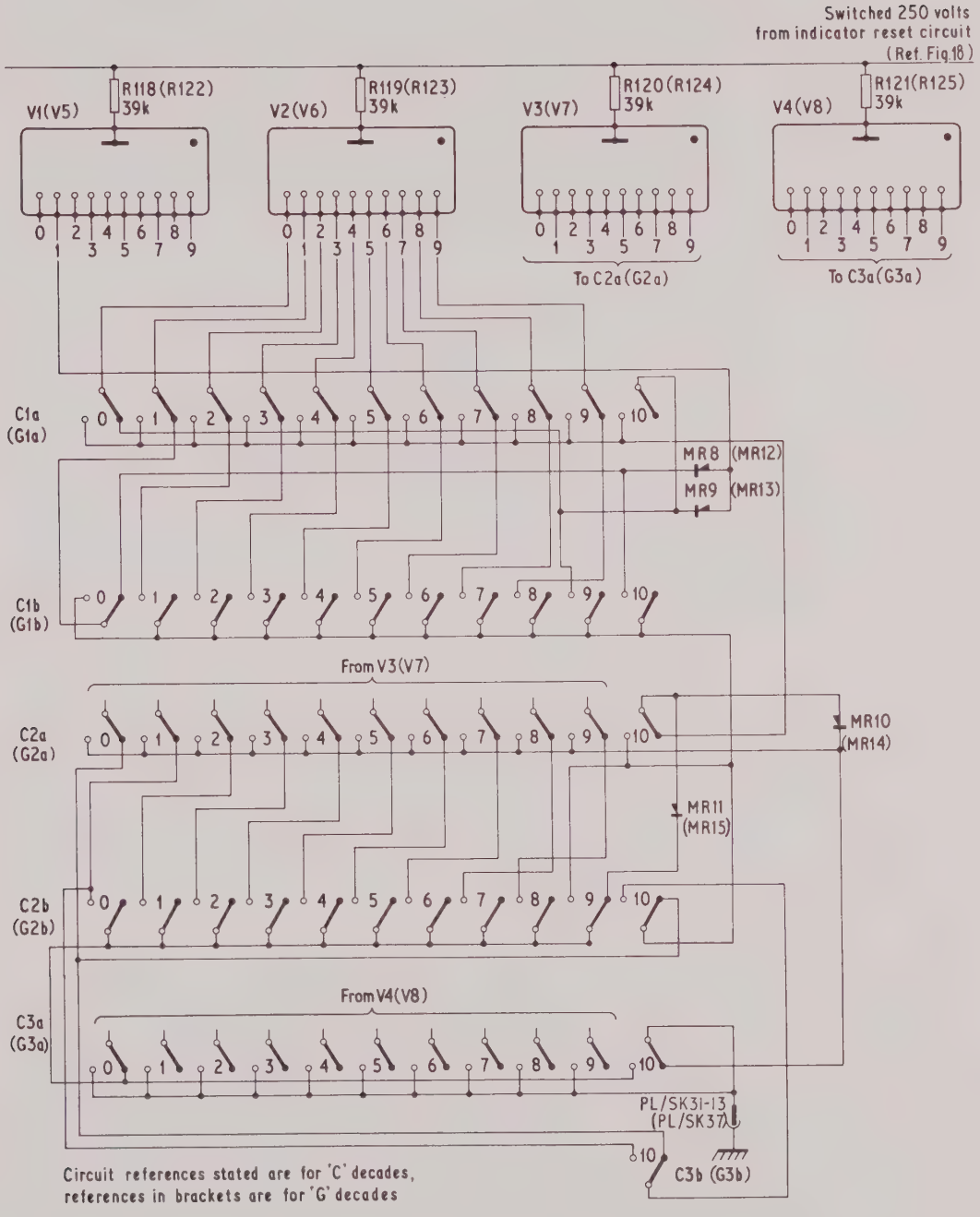


Fig.16 Digital Indicator Switching

B35I M4II
D13906/7A

given in Fig. 15 shows a simple two-decade system. Reference to Fig. 16 shows the complete system extended to cover three decades. However, this extension necessitates the addition of the diodes MR8 to MR11 whose purpose is to block alternative paths to ground that would otherwise exist. Thus

MR8 prevents V2 cathode '1' from lighting when the '10' button of decade 1 is operated.

MR9 prevents V3 cathode '0' from lighting when the '10' button of both decade 1 and decade 2 are operated.

MR11 prevents V3 cathode '0' from lighting via switch C2b'9'.

MR10 operation of the '10' button on the third decade transfers the ground connection to the 'carry' line of the second decade, but an alternative path to ground would exist for the second decade via MR11 and C2b'9'; this is blocked by MR10.

4.13.2 Operating Sequence Indicators

These indicators are the illuminated arrowheads to the right of each decade that show the correct order for the operation of the decades. Figure 17 shows how the indicators are interconnected with the decade reset buttons. This diagram shows the starting condition, with all reset buttons pressed, in which the first C decade indicator is illuminated. This indicator has the G3b'0' and G3b'1' contacts in its circuit so that the indicator is switched off when the third G decade buttons 0 and 1 are operated (out of the normal sequence) during the Calibrate procedure (see Operating Instructions). By remembering that as each decade is operated the reset button for that decade changes over, the energizing path for each indicator can be traced. This diagram also shows how the digital tubes are energized only when the appropriate G decade is operated.

4.13.3 Decimal Point Indicators

The circuit diagram for the decimal point indicators is given in Fig. 18. Both the C and G indicators operate in a similar manner. The

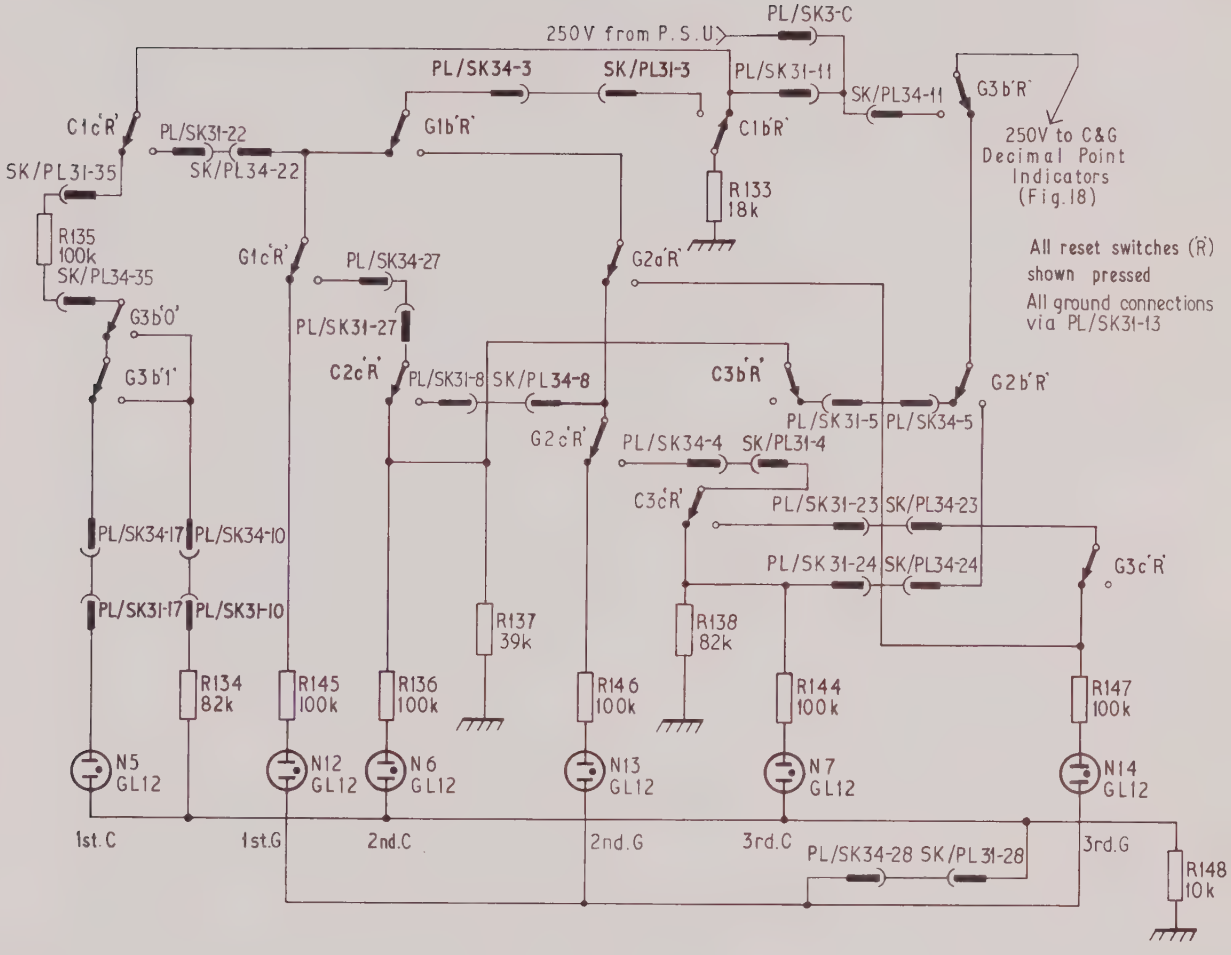


Fig. 17 Sequence Indicator Switching

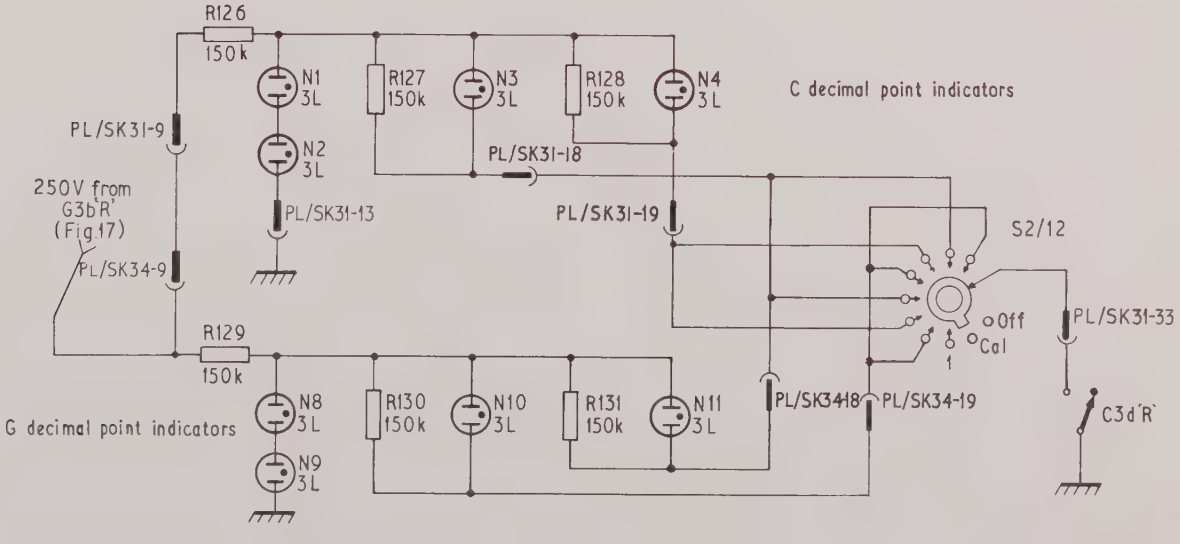


Fig.18 Decimal Point Indicators

B331 MKII
D13849A

indicators are shown in Fig. 18 in the same relative positions as they appear on the instrument when viewed from the front. Initially, the reset switch C3d'R' removes the ground return for all except the left-hand indicators; these each comprise two tubes in series but only one in each pair is visible at the front panel. With the ground return removed from the centre and right-hand tubes, the left-hand pair of tubes (C or G) operate. As soon as a ground connection is made for the centre or right-hand tubes, the tube strikes and reduces the voltage across the tubes to approximately 50V. This is sufficient to strike one tube but not two tubes in series and so the left-hand tubes are extinguished. This arrangement reduces the complexity of the indicator switching. The purpose of the parallel resistors is to reduce the current through the single tubes to approximately the same as that taken by the two tubes in series, thus equalizing the brightness.

4.13.4 Range Multiplier Indicators

The circuit diagram for these is given in Fig. 19. The switching is straightforward and requires no further explanation.

4.14 POWER SUPPLY UNIT

The Power Supply Unit provides +9V d.c. with respect to ground for the main bridge circuits; +200V d.c. for the operation of the digital and decimal point indicator tubes and, finally, -6V d.c. to operate the range multiplier lamps and the integrated circuits in the squarewave generators. The lamps are operated from a d.c. supply to prevent the injection of 50Hz ripple into the bridge circuits. The operating principle of the series stabilizer circuit is as follows:

A preset percentage of the d.c. supply is compared with MR2 zener voltage, and the difference voltage, which is amplified by VT6 is used to control the current through the Darlington pair series transistors and hence control the output voltage. Fig. 20 shows the circuit of this power supply. Overload protection is provided by VT5 in conjunction with R111. A supply overload in excess of 100mA causes a voltage drop across R111 which is sufficient to turn on VT5. This in turn bleeds away the base current from VT7 which reduces the output current to within safe limits.

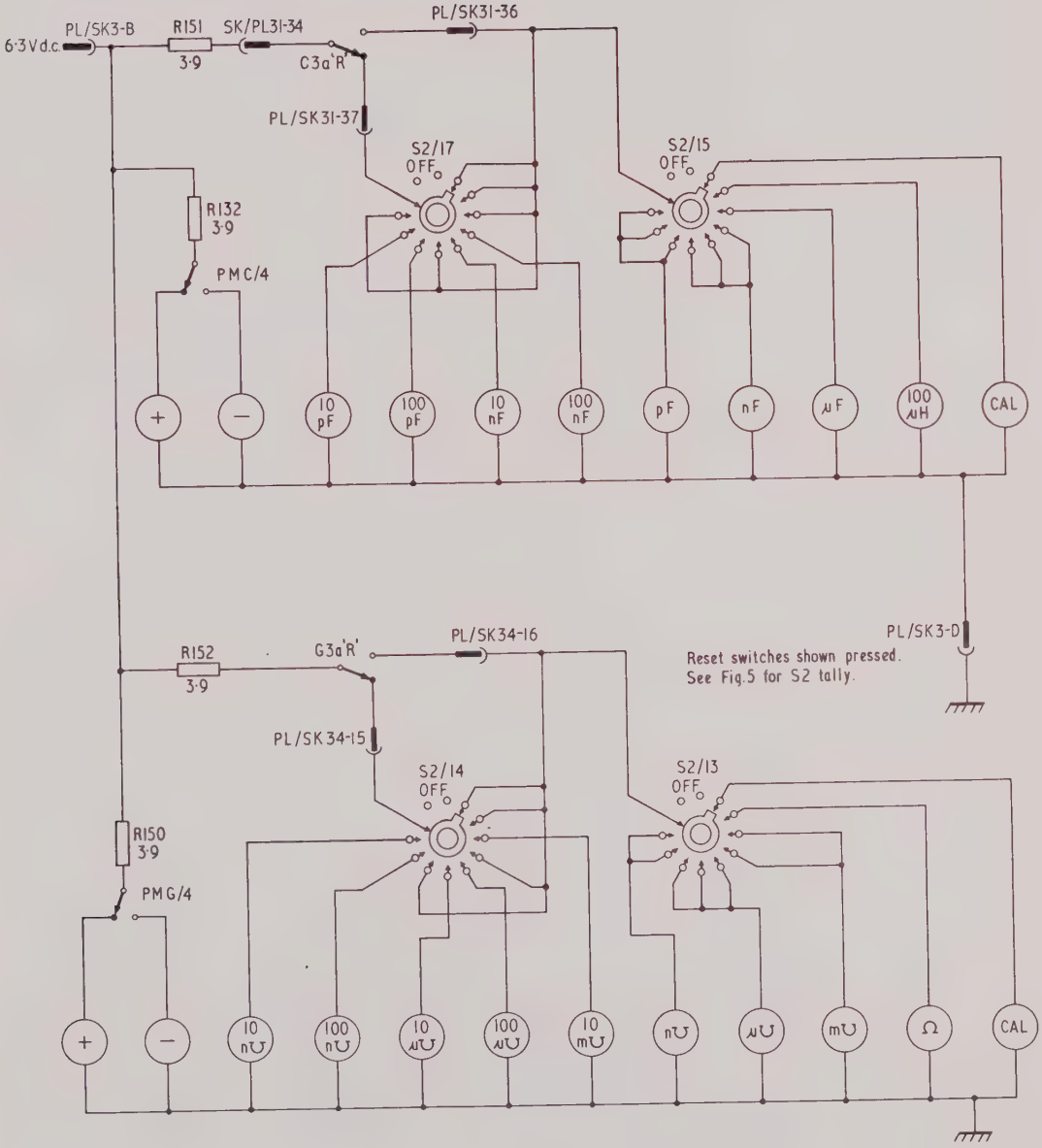


Fig.19 Range Multiplier Indicators

B331 MKII
D13849A

PART 2
5. MAINTENANCE

5.1 GENERAL

The following paragraphs give complete instructions for the adjustment of all the preset controls in the instrument. Where appropriate, tests are given to show up any departure from the original condition. Since these operations have a considerable bearing on the performance and accuracy of the instrument, it is essential that they should be performed only by skilled operators. A table of d.c. voltages is given but it is stressed that these are typical values and variations up to ±10% should not be regarded as serious. Since extensive operations are to be performed, it is recommended that the capacitance standard C9 (ST25) be temporarily replaced by a suitably mounted good quality capacitor of approximately 25pF. A general view of the instrument is given in Fig. 21.

The upper, middle and lower decades in both the C and G systems are known respectively as the first, second and third order decades. For convenience of notation, these are referred to in the following instructions as decades C1, C2, C3, G1, G2 and G3. Small roman letters following such a reference indicate separate switches operated by a particular button and, finally, the capital letter R or numerals 0, 1, 2.... etc. up to 10 signify the operated button (R indicates 'Reset'). For example, the reference G2a4 means switch 'a', button 4 on the middle, or second order G decade. If the reference is given as G2-4, it means that the particular switch is not significant.

CAUTION: Although the electronic circuits in general operate from a 9-volt supply, there is a 200-250V d.c. supply to the digital indicator tubes. Due precautions should be taken when operating on or near these tubes.

5.2 PRELIMINARY MEASUREMENT CHECK

The following procedure affords a rapid check on the correct functioning of each range of the bridge. Using the Kelvin clip leads, connect a capacitor of value between 3 and 10pF as for a normal measurement.

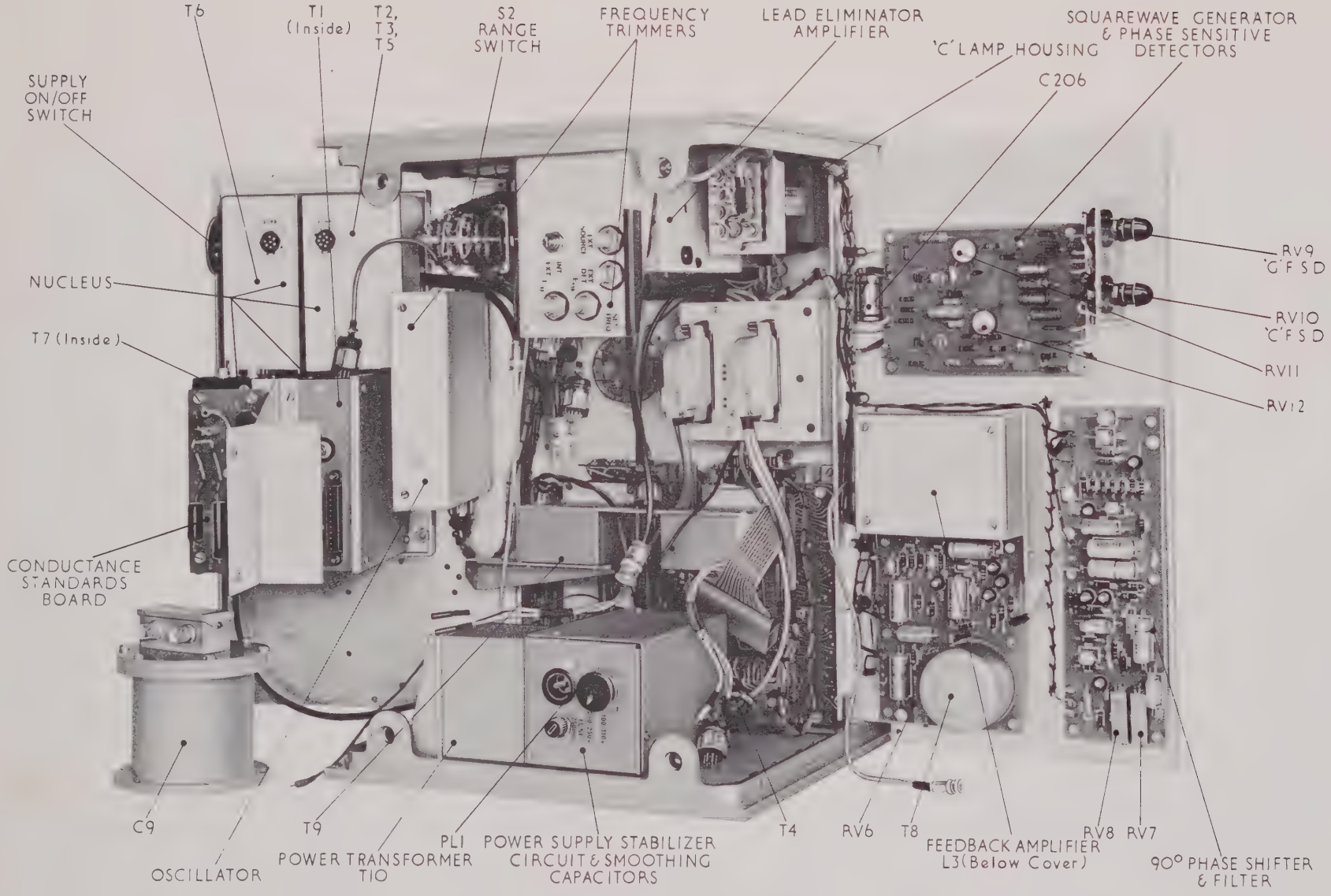


Fig.21 General view with Top and Bottom Panels open

Since this is effectively a range check, the actual value of the component is immaterial; also, the accuracy of the bridge trim is of little importance.

Set the Range switch to 8 and note that the value of the capacitance is indicated directly on the C meter. Move the range switch to 7 and press buttons C1-0 and G1-0; check that the meter indication is approximately as before. Move the Range switch to 6 and press buttons C2-0 and G2-0; the meter should again indicate approximately as before. Press all reset buttons and remove the capacitor.

Set the Range switch to 5 and connect a resistor of value between 10kΩ (100μMho) and 30kΩ. The conductance of the component should be indicated directly on the G meter. Move the Range switch to 4 and press buttons C1-0 and G1-0; check that the meter indication is approximately as before. Move the Range switch to 3 and press buttons C1-0 and G2-0; check that the meter again indicates approximately as before. Press all reset buttons and remove the resistor.

Set the Range switch to 2 and connect a 10Ω resistor (100mMho). Check that the meter indicates approximately 100mMho, i.e. approximately f. s. d. Move the Range switch to 1 (Low Impedance Range); the meter should now indicate the <u>resistance</u> value of the component, i.e. 10Ω (also f. s. d.).

5. 3 DECADE PUSH BUTTON AND VERNIER CHECK

5.3.1 Decade Push Buttons

Set the Range switch to Calibrate and press all reset buttons. Press each C1 button in turn and check that the C meter indication corresponds with each digit pressed. Press the C1-R button. Repeat this procedure with the G1 decade, checking the indications on the G meter. Press buttons C1-0 and G1-0. Press each C2 button in turn and check the C meter indicates as before. Press button C2-R and repeat the procedure for the G2 decade. Press buttons C2-0 and G2-0 (buttons C1-0 and G1-0 should remain pressed). Repeat the procedure for the C3 decade then press button C1-R. Finally, press button G3-1 and check that the G meter is at approximately f. s. d. Press all reset buttons.

5.3.2 Vernier Check

Press the G3-1 button. Carefully check the settings of the Trim C and G, Zero and FSD controls. Turn each Vernier control in from zero to maximum and check that the appropriate meter indication increases linearly to f. s. d. A slight discrepancy in C full scale reading can be corrected by adjustment of RV15 located behind the C vernier control. With the meter indication at f. s. d., turn the appropriate polarity switch to '-' and check that the meter indication remains substantially unchanged. Return the polarity switches to '+', the Vernier controls to zero and press button G3-R.

5.4 REMOVAL OF THE REAR COVER AND SIDE PLATES

To remove the rear cover of the instrument, proceed as follows:

(1) Remove all plugs from the instrument.

(2) Stand the instrument face downwards on its handles, release the four quick release fasteners on the rear panel and remove the cover.

(3) Lay the instrument on one side and remove the four 2B.A. cheesehead screws that secure the uppermost side plate. The side plate complete with handle can then be removed.

(4) Transfer the instrument to its other side, remove the four 2B.A. screws in the other side plate and remove the plate.

5.4.1 To release the top Hinged Panel:

Remove the six 2B.A. cheesehead screws, three each side of the top panel, and remove the two 4B.A. screws from the bracket beneath the top panel; all eight screws are painted red. The panel is then free to be raised.

5.4.2 To release the bottom Hinged Panel:

(1) Lay the instrument on its left-hand side.

(2) Set the Range switch to the OFF position and, using a 1/16 inch Allen key, release the two grub screws in the shaft coupling, the control knob of the Range switch

should then be pulled away from the front panel to its fullest extent thus disengaging the coupling.

(3) Disconnect all plug/socket connectors within the instrument. The plugs and sockets on the top of the Nucleus unit are made accessible by removing the small angled aluminium plate, held on by two 6B.A. screws.

(4) Remove the six 2B.A. screws (3 in each side casting). Remove the six screws in the base plate of the standard capacitor, and support it, then swing open the bottom panel taking care not to trap or damage any of the cables. All units of the instrument are then completely accessible.

5.4.3 Removal of the Nucleus Sub-Unit

The Nucleus unit is fitted to the bottom hinged panel and is held by four 2B.A. and two 4B.A. screws, the heads of which are proud of the panel. The Nucleus must be supported during removal of these screws, otherwise damage to the dog-coupling or the Range switch may result. On replacing the Nucleus tray ensure that the dog coupling is correctly engaged.

5.4.4 Re-assembly

After ensuring that no leads can be trapped or damaged, close the bottom hinged panel and secure it in position. Connect up all internal plugs and sockets and replace the small angled metal plate on the nucleus unit. Locate the coupling of the Range switch with the knob pointer in the OFF position and tighten the Allen grub screws in the coupling. Close the top hinged panel and secure it with the red 2B.A. and 4B.A. screws; the two 4B.A. screws are fitted above the Nucleus. Replace both side panels and then stand the instrument on its handles and replace the rear cover. A 90^{o} turn of each fastener is all that is required to lock it.

The section of the Range switch contained in the nucleus unit is not operated by the front panel control when the bottom hinged panel is

open. Separate provision must therefore be made to operate the dismounted part of the switch. For example, temporary index marks can be made on the chassis and the spindle but note that clockwise rotation of the front panel control must be accompanied by an equal clockwise rotation of the spindle.

6 SETTING-UP INSTRUCTIONS

6.1 TEST EQUIPMENT REQUIRED

The following items of test equipment are required for the calibration of the instrument. Miscellaneous components, used in some tests, are detailed in the appropriate paragraphs.

(1)	Timer Counter	Racal Type SA535
(2)	Double Beam Oscilloscope	Telequipment D43 with Amplifier Type C
(3)	Multimeter: 20 000Ω/V	AVO 8
(4)	Millivoltmeter	Comark Type 120
(5)	Digital Voltmeter 200mV	Digitec model 402 or 401
(6)	Standards (see below)	

(6) Conductance standards as follows: 100mMho (10Ω), 10mMho (100Ω), 1mMho (1kΩ), 100μMho (10kΩ), 10μMho (100kΩ). All are Alma Type JF3/2Z. Certified to 0.001% at 1kHz.

Capacitance standards as follows: 10pF Wayne Kerr Type ST10, 100pF General Radio Type 1404-9702, 1000pF General Radio Type 1404-9701. Certified to 0.002% at 1kHz.

Other test equipment of equivalent specification can be used.

6.2 CHECKING 9V SUPPLY

Before commencing any tests or adjustements, check the +9V supply by connecting a multimeter (10V d.c. range) and an oscilloscope between chassis (-) and any convenient point on the +9V line. The voltage should be between 8.8 and 9.2V; the ripple should not exceed 10mV pk-pk.

6.3 OSCILLATOR FREQUENCY ADJUSTMENT

Frequency adjustment is by means of variable resistor RV18. The A.I.C. (adjust in circuit) capacitor C61 may or may not be fitted; if it is not, accommodation for it is provided in case it becomes necessary after servicing. RV18 is mounted on the main oscillator p-c board and is accessible through the top of the oscillator screening box, at the left-hand end of the box viewed from the rear.

To check the oscillator frequency, remove the outer cover - see Section 5.4 - and connect the input terminals of the Timer Counter (in Section 6.1) to the E_{+10} socket of the Offset Winding at the rear of the instrument. The frequency should be 1591.55Hz nominal (628.318μS); if necessary adjust the frequency to within 0.01% by means of RV18 and to its precise value by C84 (SET FREQ. control) situated on the rear sub-panel of the instrument.

Although no provision is made for the adjustment of the oscillator output level, a knowledge of its value may be useful in fault diagnosis. An oscilloscope connected to the E_{+10} socket should show a clean sinewave of approximately 1 to 1.5 volts peak-to-peak amplitude.

6.4 SETTING-UP THE CALIBRATION CONTROLS

Set the Range switch to Calibrate and press the decade button G3-0. Adjust the Trim C and Trim G controls for zero indication on both meters. Press button C3-1 and adjust the F.S.D. control until the C meter is at f.s.d. If the control has insufficient range, RV14 should be adjusted to give f.s.d. with the FSD control set to mid-position. Adjust the Zero control for zero indication on the G meter. Repeat if necessary. Press buttons C3-0 and G3-1. Adjust potentiometer RV8 until the G meter reaches f.s.d. Adjust potentiometer RV7 for zero indication on the C meter.

6.5 FEEDBACK AMPLIFIER

The tuning of the feedback amplifier requires only the removal of the outer cover - see Section 5.4. However, if further checks on the

amplifier are to be made, it may be more convenient to raise the amplifier panel - see Section 5. 4. 1 and 5. 4. 2. Set the Range switch to Calibrate, both Vernier controls to zero and press the reset buttons (red) on all decades. Press button G3-0 and check the bridge trim. With the oscilloscope connected to the amplifier output at C26, check that the residual signal, together with the noise and hum, does not exceed 1V pk-pk. Move the oscilloscope connection to the output of the bandpass filter (pin 41). Set the G Vernier to give f. s. d. on the G meter; check that the Vernier setting is not greater than 030 and that the oscilloscope indicates approximately 2.0V pk-pk. Set the G Vernier until limiting just occurs at the amplifier output; this output should be approximately 4.7V pk-pk.

The switching of the amplifier feedback (i.e. closed loop gain) is now checked as follows: Depress button C1-0 and press the reset buttons on all other decades. The C meter should read zero. Press button C1-10 and adjust the F. S. D. control to achieve full scale deflection of the meter (Note: if a slight zero error was noted above, make an appropriate correction when setting the F. S. D.). Adjust the Zero control for zero reading (centre scale) on the G meter. Press buttons G1-0 and C1-0, check the bridge trim and then press button C2-10. The C meter should indicate full scale deflection ±0.3 division and the G meter should indicate zero ±0.3 division.

Press button C2-0 and G2-0, check and if necessary adjust the trim. Press button C3-10; the C meter should indicate full scale deflection ±0.5% and the G meter should indicate zero ±0.5%.

Press buttons C3-0 and G3-0 and trim the bridge. Press button C3-1, the C meter should indicate full scale deflection ±0.5% and the G meter should indicate zero ±0.5%. If the G meter reading is significantly different from zero (but not more than 5%) it is permissible to make a small correction by altering the amplifier tuning (not more than three turns of the tuning slug) in such a direction as to eliminate the phase error; the tuning slug is accessible through a hole in the top hinged panel. Finally, press all reset buttons.

6.6 LEAD ELIMINATOR AMPLIFIER

6.6.1 Tuning Check

The IN/OUT switch on the lead eliminator amplifier must be set to IN before proceeding with these tests. Connect a resistor of value 100Ω (any type and tolerance) in series with another of value 10Ω; the latter must be a carbon or metal film type. With the bridge set to Range 3 and using the low impedance leads (Reference D15466), trim the bridge and then connect the various clips to the 100Ω resistor as for a normal measurement (see Operating Instructions). Balance the bridge on all decades and note the full C value very carefully. Now move the appropriate red lead from the junction of the two resistors to the free end of the 10Ω resistor, leaving the other red lead and both black leads (lead eliminator) unaltered. Any change in C value from that previously noted signifies mis-tuning of the lead eliminator amplifier. If this is the case, correct the tuning by adjusting the core of the Lead Eliminator inductor L4 until the two G values (as described above) are identical.

6.6.2 Gain Check

Connect two resistors of value 10Ω and 1Ω in series. These should be high stability ±5% components. With the instrument set to Range 2 and using the procedure described above, measure the 10Ω resistor; note the G value. Move the appropriate red lead to the free end of the 1Ω resistor (i.e. the lead resistance is effectively increased by 1Ω) and rebalance the bridge; note the new G value. The gain of the lead eliminator amplifier is given by

$$\text{L/E gain} = \frac{10}{\%\text{ change in G value}}$$

The figure thus obtained should not be less than 270. Repeat the measurement on Range 3 using 100Ω and 10Ω resistors, and again on Range 4 using 1000Ω and 100Ω resistors. The gain should not be less than 210 and 65 respectively.

6.7 SETTING-UP THE CONDUCTANCE STANDARDS

Set the Range switch to 5 and trim the bridge as accurately as possible. Using the Kelvin clip leads, connect the external 100μMho (10k) standard to the bridge. Balance the bridge on all decades of C and G. If the polarity switch is altered the bridge must be re-trimmed. Note the G value as indicated on the bridge and compare this with the stated value of the standard. It is convenient to make this comparison in terms of parts per million (p. p. m.) because when button G1-10 is engaged, one small meter division (2% of f. s. d.) is equivalent to 20 p. p. m. Thus, if the G value is set up as 10, 0, 0 on the decades and, nominally, zero on the meter (rather than 9, 9, 9 on the decades and 10 on the meter), any departure from the nominal can be read from the meter in terms of parts per million.

N. B. On centre zero meters 1 division (1% of f. s. d.) would be equivalent to 10 p. p. m.

Also, since the accuracy of the decades is inherently greater than that of the meter, it is better to have as much as possible of the value on the decades.

The internal major conductance standard (R22) is adjusted, if necessary, by adding low value resistors in series with it (provision is made for this on the Standards Board - see Fig. 21) to the extent of 1Ω for every 100 p. p. m. error. Note that the tolerance of R22 is always negative. At this stage, the value of the standard, R22, should be adjusted only to the nearest 50 p. p. m. (i.e. to the nearest 0.5Ω) and the padding resistors should be soldered in place temporarily. Press all reset buttons.

Set the Range switch to 6 and carefully trim the bridge. Connect the 10μMho external standard and balance the bridge fully on both C and G; record the values. Repeat this procedure on Ranges 3 and 4, using 10mMho and 1mMho standards respectively.

Change the bridge leads for the Low Impedance leads (D15466), set the Range switch to 2 and carefully trim the bridge. Connect together

the green (neutral) leads and connect black to red on each lead (not to the other lead). Connect the 100mMho external standard to the bridge, with the black leads nearest the component, balance completely and record the G value. This value must be corrected to take account of the lead resistance and switch and transformer impedances. This will be equal to 12mΩ for the leads plus approximately 50mΩ transformer and lead impedances, divided by the improvement factor given by the lead eliminator system on this range. This improvement factor is equal to the lead eliminator gain as measured in Section 6. 6. 2. Suppose this figure to be 400 on Range 2 then the effective lead resistance is

$$\frac{62}{400} = 0.15\text{m}\Omega$$

and 0.15mΩ in 10Ω is equivalent to 15 p. p. m. Thus 15 p. p. m. (or whatever figure is obtained, depending on the L/E gain of the particular instrument) must be added to the G value noted at the beginning of this paragraph.

Examine the recorded G values and note the spread of the errors (i.e. the difference between the greatest negative and the greatest positive). If this is less than 100 p. p. m. , no adjustment is necessary; if more than 100 p. p. m. proceed as follows. The main G standard must be adjusted on Range 5 to bring this level to the correct absolute value. For example, it may be necessary to deliberately set Range 5 high or low by 50 p. p. m. in order to spread the range errors about zero. With the bridge measuring 100μ℧ (10k) using Kelvin leads on Range 5, press buttons G1-9 and G2-10 and note how this reading compares with that at G1-10 and G2-0. Adjust the middle decade standard (R23-100k) by adding series resistors (10Ω is equivalent to 100 p. p. m. error) until the difference between the two readings is not more than 1% on the meter.

Press buttons G2-9 and G3-10; check that the G meter indication is within 1% of that obtained in the previous paragraph. If not, adjust the value of the G3 standard (R24-1MΩ) with a series resistor until the condition is met.

Press button G3-9 and set the G Vernier to full scale. Check that the G meter indication is within 1% of that obtained in the previous paragraph. If not, adjust the Vernier standard (R25-1MΩ) with a series resistor until the condition is met. Return the Vernier control to zero, fully counter-clockwise.

6.8 ELIMINATION OF CAPACITANCE OF THE G STANDARD

With the bridge set to Range 5 and the Kelvin measurement leads in place but with the clips apart, carefully trim the bridge. Connect a carbon or metal film resistor of value 10kΩ + 0 - 0.1% to the measurement leads and balance the bridge on all decades.

Note the C meter indication and adjust the trimmer capacitor C12 (on the Standards Board, see Fig. 21) until this is reduced to +0.3pF - this being the capacitance between the ends of a typical type V resistor. If necessary, a fixed polystyrene capacitor of not more than 5pF may be added in parallel with the trimmer C12. Press button G1-9 and G2-10 and re-check the C reading. This should not deviate by more than 1%. If there is a deviation, adjust C85 to correct it. Press button G2-9 and G3-10 and check that the minor term has not altered by more than 1%.

6.9 SETTING-UP THE CAPACITANCE STANDARD

Set the Range switch to 8. Connect the precision 10pF standard capacitor to the Unknown sockets. If the Wayne Kerr Standard Capacitor Type ST10 is used it must be connected by means of Triaxial-to-B.N.C. coaxial adaptors Type LA331; in this case, the bridge must be trimmed with the adaptors in place and neutrals joined. With the bridge fully balanced, record the C and G values.

Set the Range switch to 7 and measure the C and G values of the 100pF standard capacitor. With the neutrals joined compare these results, and those of the previous measurement, with the absolute values as stated for the external standards. Measure the 1000pF standard on Range 6 with the neutrals joined and record the C and G values. Compare the three readings with the stated absolute values of the

standards. If the error in the measured C values is greater than 70 p. p. m., adjust the trimmer on the top of C9 (see Fig. 21) until the mean error is as near to zero as possible; repeat the tests.

With the 100pF external standard capacitor connected and the bridge fully balanced, check that the three C decade combinations (i.e. buttons 10-0-0 or 9-10-0 or 9-9-10) all give the same result.

Press button 9 on all three C decades and set the C Vernier to 10. The C meter indication should be exactly as before; if necessary, adjust RV15 to meet this condition. Potentiometer RV15 is located under the G range display lamp housing on the polarity switch back plate. (See Fig. 25). Compare errors on all ranges except Range 1. The overall included error should not exceed 140 p. p. m. Press all reset buttons.

6. 10 SETTING-UP THE D. V. M. OUTPUTS

The following procedure is identical for both the C and G DVM outputs. Component references are given for the C system, the corresponding G components being added in parentheses. Connect the digital voltmeter (100mV range) to the C DVM (G DVM) output. Set the instrument controls as for calibration and press button G3-0.

The preset potentiometer RV12 (RV11) on the phase sensitive detector board - see Fig. 21 - must be adjusted until the digital voltmeter indicates zero, but first check that the control has enough latitude to take up any drift in the zero. Check that the control can be set to give at least 3mV on each side of zero before finally setting to zero.

Press the button C3-1 and adjust either the FSD control or the C Vernier (G Vernier) until the C meter (G meter) indicates exactly f. s. d. Set the DVM Output control RV10 (RV9) on the rear panel to its maximum clockwise position. Connect a 100kΩ ±1% resistor across the digital voltmeter input terminals. Adjust the FSD control (or the appropriate vernier) until the digital voltmeter indicates approximately 105mV.

Disconnect one side of the 100kΩ resistor and turn RV10 (RV9) to its fully counter-clockwise position. Check that the digital voltmeter indication is less than 100mV. Finally, adjust RV10 (RV9) to give 100mV across the 100kΩ load and then repeat the Calibration procedure given in Section 6.4.

6.11 NUCLEUS UNIT

There are no preset controls or adjustments in the nucleus unit and it should not in any circumstances be dismantled. However, the following tests will serve as a guide to its serviceability. When making connections to individual pins of plugs and sockets, it is advisable to use a mating connector to which short lengths of wire are attached. It is assumed that the nucleus is in position in the main assembly.

6.11.1 Voltage and Phase Checks

Connect the millivoltmeter to the external oscillator and set the output to 300mV r.m.s. at 1592Hz. Connect one beam of the oscilloscope to the ouput of the oscillator. The signal displayed will be the Reference signal. Remove the test leads from the E and I sockets. Connect the external oscillator between pin 1 (ground) and pin 11 of SK10, noting that the reading on the millivoltmeter does not fall below 295mV r.m.s. Any marked decrease beyond this point indicates a short circuit or partial short circuit in the voltage side of the assembly, in which case it should be returned to Wayne Kerr.

Set the output from the oscillator to 3V r.m.s. on load. Connect the millivoltmeter and the other beam of the oscilloscope between the E inner screen and E outer screen (ground). Measure the following voltages for each position of the Range switch and note that the output at the E socket is in phase with the reference signal at each position.

Range	R. M. S. Voltage
1	300mV
2	3mV
3	10mV
4	30mV
5	100mV
6	300mV
7	1.0V
8	3.0V

Connect SK6 pin B to ground. Transfer the positive lead of the millivoltmeter and oscilloscope to the inner conductor of the E socket. Measure the following voltages and note that the measured signal is in phase with the reference signal in each case.

Range	D. C. Voltage
2	3mV
3	10mV
4	30mV

Remove the oscillator connection from SK10.
Connect the millivoltmeter to the external oscillator and set the output to 1V r. m. s. Connect one beam of the oscilloscope to the output of the oscillator. The signal displayed will be the Reference signal. Connect the oscillator between the outer (ground) and inner of SK26. The voltmeter indication should not fall below 0.85V. Any marked decrease beyond this point indicates a short circuit or partial short circuit in the current side of the assembly and it should be returned to Wayne Kerr for repair.

Set the output from the oscillator to 1 volt on load. Connect the millivoltmeter and the other beam of the oscilloscope between the I socket outer screen (ground) and the I inner screen. Connect the I outer screen to the E socket outer screen and connect the outer of SK26 to the outer screen of the E socket. Measure the following voltages; the measured voltage should be in phase with the Reference signal in each case.

Range	R. M. S. Voltage
2	4mV
3	12mV
4	40mV
5	120mV
6	400mV
7	1.2V
8	4V

Set the Range switch to position 1. Connect the millivoltmeter, set to the 300mV range, to the output of the external oscillator and set the oscillator output to 130mV r. m. s. Connect the millivoltmeter and oscillator to SK3 between pin 5B (ground) and pin 5A, and note that the meter indication does not fall below 125mV. Set the oscillator output to 130mV r. m. s. on load and measure the following voltages; the signal at the E socket should be in anti-phase to the reference signal.

Between the E socket outer screen (ground) and E socket inner screen 4mV r. m. s.

Between the E socket outer screen (ground) and SK6 2mV r. m. s.

6. 12 REPLACEMENT OF THE DIGITAL INDICATOR TUBES

If the digit fails to energize on any of the digital indicator tubes, the cause could be either a faulty switch contact or an unserviceable tube. To ascertain the correct cause, connect one end of a crocodile clip lead to the chassis and the other end (via a prod or screwdriver blade) to the appropriate tube contact (see table below). If the digit is then energized, a switch fault is indicated and the instrument should be returned to the factory for repair. If, however, the digit still fails to energize, the tube can be replaced as described below.

PIN CONNECTIONS FOR INDICATOR TUBES GN-4 OR GR10M

Pin No.	1	2	3	4	5	6	7	8	9	10	11	12	13
Electrode	-	Anode	0	9	8	7	6	-	5	4	3	2	1

As viewed from the base, the pins are numbered in a clockwise direction from the gap.

To replace a digital tube or decimal point indicator proceed as follows:

(1) Remove the rear cover and the left and right-hand side plate and swing out the top and bottom hinged panels as detailed in Sections 5. 4, 5. 4. 1 and 5. 4. 2.

(2) Remove the power supply unit complete - this is housed in the two metal boxes at the right-hand side of the bridge viewed from the rear. The complete assembly is held onto the side plate by six 4B.A. cheesehead screws.

(3) Remove the 7 inch long tie bar situated behind the push-button switches.

(4) On removing the four 4B.A. cheesehead screws (one at each end and the other two below the push-button assembly), the complete assembly can then be removed.

(5) Withdraw the faulty indicator from the front of the assembly. Transfer the moulded rubber sleeve to the new tube and insert the tube into the assembly. The same disassembly procedure applies to both the C and G switch assemblies. Since the extreme left-hand tube is only used on 10, a faulty tube at any other position could temporarily be exchanged with this one.

(6) The decimal point indicators have long leads which must be unsoldered from the printed circuit board to permit removal.

After replacing the switch assembly, replace the power supply unit and the left-hand side plate. The procedure for re-assembling the rest of the instrument is detailed in Section 5. 4. 4.

6. 13 DC VOLTAGES

The d.c. voltages given below are typical values for guidance only, deviations of up to 10% from these values can be regarded as normal. The measurements are made with the Range switch set to Calibrate and with the bridge trimmed. The measuring instrument used is the

Comark D.C. Millivoltmeter Type 120S. Values are volts except VT13 emitter and VT5 base.

Oscillator

	Collector	Base	Emitter
VT1	5.3	4.13	3.53
VT2	6.93	5.3	4.68
VT3	9.0	4.0	3.33
VT4	9.0	4.0	3.33
VT26	3.33	1.7	1.03

Feedback Amplifier

	Collector	Base	Emitter
VT8	1.12	0.55	0
VT9	7.65	1.12	0.55
VT10	2.75	1.4	0.8
VT11	5.3	2.75	2.15
VT12	8.2	5.3	4.65
VT29	7.45	2.0	1.4

90^{o} Phase Shifter

	Collector	Base	Emitter
VT13	3.6	0.6	80mV
VT14	7.5	3.6	2.95
VT21	5.35	7.5	5.25
VT27	8.6	6.62	6.0
VT28	8.6	5.85	5.2
Junction R52/R53	0.6		

Lead Eliminator

	Collector	Base	Emitter
VT22	1.65	0.92	0.38
VT23	7.70	1.65	1.05
VT24	3.4	7.7	9.0

Power Supply

	Collector	Base	Emitter
VT5	10.5	-7mV	-0.44
VT6	10.5	5.9	5.3
VT7	17.8	10.5	9.8
VT25	17.8	9.8	9.2

LIST OF COMPONENTS

When ordering spare parts, please quote the Instrument Type and Serial Number, and the circuit reference and value of the repaired component.

Resistors, fixed

Cct. Ref.	Description		Style or Supplier and Type
R1	7.5k	0.05%	Welwyn Vishay Type 4804
R2	15k	0.05%	" " " "
R3	Not Used		
R4	2.7k	5%	Waycom Piher WP051
R5	3.3k	5%	" " "
R6	330	5%	Waycom Piher WP051
R7	470	5%	" " "
R8	4.7k	5%	" " "
R9	180	10%	S. T C. Silistor 502K/181/RY/1
R10	4.7k	5%	Waycom Piher WP051
R11	470	5%	Waycom Piher WP051
R12	Not Used		
R13	2.7k	5%	" " "
R14	100k	5%	" " "
R15	3.9k	5%	" " "
R16	12k	5%	" " "
R17	12k	5%	" " "
R18	2.2k	5%	" " "
R19	39	5%	" " "
R20	Not Used		
R21	470k	5%	Electrosyl TR5
R22	9995	0.01%	Alma Type JC22
R23	99950	0.01%	Alma Type E205
R24	1M	0.1%	Alma Type MA1
R25	1M	0.1%	Alma Type MA1
R26	2.2k	5%	Waycom Piher WP051
R27	15k	5%	" " "
R28	68k	5%	" " "
R29	680	5%	" " "
R30	220	5%	" " "
R31	1k	5%	" " "
R32	47	5%	" " "
R33	2.2k	5%	" " "
R34	560	5%	" " "
R35	12k	5%	" " "

Cct. Ref.	Description		Style or Supplier and Type
R36	10	5%	Waycom Piher WP051
R37	100	5%	" " "
R38	1k	5%	" " "
R39	180k	5%	" " "
R40	1k	5%	" " "
R41	10	5%	" " "
R42	330	5%	" " "
R43	1k	5%	" " "
R44	10k	5%	" " "
R45	680	5%	" " "
R46	1k	5%	Waycom Piher WP051
R47	10k	1%	Electrosyl TR5
R48	10k	5%	Waycom Piher WP051
R49	22	5%	" " "
R50	12k	5%	" " "
R51	1k	5%	" " "
R52	1k	5%	" " "
R53	270	5%	" " "
R54	1.5k	5%	" " "
R55	Not Used		
R56	Not Used		
R57	Not Used		
R58	Not Used		
R59	Not Used		
R60	Not Used		
R61	Not Used		
R62	Not Used		
R63	8.2k	5%	Waycom Piher WP051
R64	8.2k	5%	" " "
R65	8.2k	5%	" " "
R66	8.2k	5%	" " "
R67	5.6k	5%	" " "
R68	390k	5%	" " "
R69	390k	5%	" " "
R70	1k	5%	" " "
R71	1k	5%	" " "
R72	5.6k	5%	" " "
R73	12k	1%	Metal film 1/8 Watt Trel Type TM
R74	15k	1%	" " " " " " "
R75	2.2k	5%	Waycom Piher WP051
R76	12k	1%	Metal film 1/8 Watt Trel Type TM
R77	15k	1%	" " " " " " "
R78	Not Used		
R79	Not Used		
R80	Not Used		

Cct. Ref.	Description		Style or Supplier and Type
R86	2.2k	5%	Waycom Piher WP051
R87	Not Used		
R88	1k	5%	Waycom Piher WP051
R89	68	5%	" " "
R90	1.5k	5%	" " "
R91	560	5%	Waycom Piher WP051
R92	1k	+0	Alma MD1/4, Painton
R93	1k	-0.1%	PMF60/50 PPM or Welwyn 4014C
R94	62k	5%	Waycom Piher WP051
R95	62k	5%	" " "
R96	Not Used		
R97	Not Used		
R98	470	5%	Waycom Piher WP051
R99	2.7k	5%	Waycom Piher WP051
R100	15k	5%	" " "
R101	47	5%	" " "
R102	Not Used		
R103	Not Used		
R104	3.3k	5%	Waycom Piher WP051
R105	3.3k	5%	" " "
R106	Not Used		
R107	1.5k	5%	Waycom Piher WP051
R108	6.8k	5%	" " "
R109	1.0k	5%	" " "
R110	680	5%	" " "
R111	4.7	10%	RFG-1 Type S
R112	5k	5% 1.5W	Style RWY3-J
R113	330k	5%	Waycom Piher WP051
R114	Not Used		
R115	5.6k	5%	" " "
R116	A.I.C	5%	" " "
R117	2.2k	5%	" " "
R118	39k	5%	" " "
R119	39k	10%	" " "
R120	39k	10%	" " "
R121	Not Used		
R122	Not Used		
R123	39k	5%	Waycom Piher WP051
R124	Not Used		
R125	Not Used		
R126	Not Used		
R127	Not Used		
R128	150k	5%	Waycom Piher WP051
R129	Not Used		
R130	Not Used		

Cct. Ref.	Description	Style or Supplier and Type
R131	Not Used	
R132	3.9Ω ±0.5Ω 0.5W	Radio Spares 'Low Ohm'
R133	18k 5% 3W	RWV4-J
R134	82k 5% 1W	Waycom Piher WP051
R135	100k 5%	" " "
R136	100k 5%	" " "
R137	39k 10% 2W	Radio Resistor Type 0
R138	82k 5% 1W	Waycom Piher WP.11
R139	Not Used	
R140	Not Used	
R141	Not Used	
R142	100 5%	Waycom Piher WP051
R143	1.8k 5%	" " "
R144	100k 5%	" " "
R145	100k 5%	" " "
R146	100k 5%	Waycom Piher WP051
R147	100k 5%	" " "
R148	10k 5%	" " "
R149	Not Used	
R150	3.9Ω ±0.5Ω 0.5W	Radio Spares 'Low Ohm'
R151	3.9Ω 0.5W	" " " "
R152	3.9Ω 0.5W	" " " "
R153	Not Used	
R154	Not Used	
R155	180 5%	Waycom Piher WP051
R156	18k 1%	Electrosyl Type TR5
R157	47k 1%	" " "
R158	180k 1%	" " "
R159	3.9k 5%	Waycom Piher WP051
R160	15k 1%	Electrosyl Type TR5
R161	15k 1%	" " "
R162	270k 1%	" " "
R163	270k 1%	" " "
R164	1.5k 5%	Waycom Piher WP051
R165	100 5%	" " "
R166	120 5%	" " "
R167	3.9k 5%	" " "
R168	82 5%	" " "
R300	1k 5%	Waycom Piher WP051
R301	2.2k 5%	" " "
R302	2.2k 5%	" " "
R303	100 5%	" " "
R304	100Ω 5%	" " "

Cct. Ref.	Description			Style or Supplier and Type
R305	27k	5%		Waycom Piher WP051
R306	10k	5%		" " "
R307	22Ω	5%		" " "
R308	1k	5%		" " "
R309	1k	5%		" " "
R310	1k	5%		" " "
R311	1k	5%		" " "
R312	1k	5%		" " "
R313	1k	5%		" " "

Resistors, variable

RV1	Not Used			
RV2	1k 3-turn helipot			Bourns 3510S-71-102 or
RV3	1k " "			Reliance HEL.05-B03
RV4	1k 10-turn helipot			Bourns 3600S-1-102 (Knobpot)
RV5	1k " "			" " "
RV6	100	10% W-W		Reliance Type WL35 P.C. or STD
RV7	1k	10% W-W		" " " " "
RV8	1k	10% W-W		" " " " "
RV9	5k	20%		Plessey Type E
RV10	5k	20%		" " "
RV11	25k	20%		Daval Type 80/P
RV12	25k	20%		" " "
RV13	10k LIN	20%		Plessey Type E
RV14	25k	20%		Daval Type 80/S
RV15	500	10% W-W		Reliance Type WL35
RV16	25k LIN	20%		Plessey Type E
RV17	Not Used			
RV18	100	10%		Reliance Type WL35 or WL35PC
RV19	10k	20%		Plessey Type G Mk2A

Capacitors

C1	1592Hz 13,250p 1000Hz 21,000p	1%	200V	Johnson & Mathey Type C33W
C2	1592Hz 6,660p 1000Hz 10,660p	0.5%	350V 200V	Johnson & Mathey Type C33W
C3	700p	10%	125V	GEC Type PF
C4	400µ	+50% -20%	15V	Wima Printilyt
C5	50µ	+50% -20%	15V	Wima Printilyt
C6	400µ	+50% -20%	15V	Wima Printilyt
C7	400µ	+50% -20%	15V	Wima Printilyt

Cct. Ref.	Description			Style or Supplier and Type
C8	330p	2%	125V	GEC Type PF
C9	25p			Wayne Kerr Type ST25 (C standard)
C10	250p	±1%		GEC Type PF
C11	10p	±1pF	125V	S. E. I.
C12	1.5 -19.5p	Variable		Mullard C004 EA/18E
C13	400µ	+50% -20%	15V	Wima Printilyt
C14	10µ	+50% -20%	15V	Wima Printilyt
C15	0.1µ	2%	125V	GEC Type PF
C16	Not Used			
C17	10µ	+50% -20%	15V	Wima Printilyt
C18	250µ	+50% -20%	15V	Wima Printilyt
C19	400µ	+50% -20%	15V	Wima Printilyt
C20	1000p	2%	125V	GEC Type PF
C21	400µ	+50% -20%	15V	Wima Printilyt
C22	2000p	2%	125V	GEC Type PF
C23	2000p	2%	125V	GEC Type PF
C24	100p	2%	125V	GEC Type PF
C25	400µ	+50% -20%	15V	Wima Printilyt
C26	100µ	+50% -20%	15V	Wima Printilyt
C27	10 000p	2%	125V	GEC Type PF
C28	10µ	+50% -20%	15V	Wima Printilyt
C29	100p	2%	125V	GEC Type PF
C30	0.01µ	2%	125V	GEC Type PF
C31	5000p	2%	125V	GEC Type PF
C32	400µ	+50% -20%	15V	Wima Printilyt
C33	5µ	+50% -20%	15V	Wima Printilyt
C34	Not Used			
C35	Not Used			
C36	Not Used			
C37	Not Used			

Cct. Ref.	Description			Style or Supplier and Type
C38	1µ	±20%	63V	Wima Type MKS
C39	10µ	+50% -20%	6V	Wima Printilyt
C40	0.01µ	10%	150V	GEC Type PFT
C41	0.01µ	10%	150V	" " "
C42	0.01µ	10%	150V	" " "
C43	0.01µ	10%	150V	" " "
C44	Not Used			
C45	1000µ	+50% -20%	6.4V	Mullard Type C437/AR/C1000
C46	5µ	+50% -20%	15V	Wima Printilyt
C47	5µ	+50% -20%	15V	Wima Printilyt
C48	0.1µ	2%	125V	GEC Type PF
C49	5µ	+50% -20%	15V	Wima Printilyt
C50	250µ	+50% -20%	15V	Wima Printilyt
C51	6800µ	20%	150V	GEC Type PFT
C52	100µ	+50% -20%	15V	Wima Printilyt
C53	0.5µ	20%	150V	GEC Type PF
C54	Not Used			
C55	Not Used			
C56	220p	2%	125V	GEC Type PF
C57	500p	2%	125V	GEC Type PF
C58	10µ	+50% -20%	6V	Wima Printilyt
C59	20µ	10%	150V	GEC Type PFT
C60*	3-30p	Variable		Mullard Type 7876
*When fitted				
C61*	A.I.C.	±5%	350V	Lemco Type 1106R SW. Value selected on test from 20, 30, 39 or 50pF.
C62	0.1µ	20%	100V	Wima Type MKS
C63	Not Used			
C64	200µ	+50% -20%	35V	Wima Printilyt
C65	25µ	+50% -20%	35V	Wima Printilyt
C66 C67	16+16µ	+50% -20%	350V	Hunts Type JF413T

Cct. Ref.		Description			Style or Supplier and Type
C68		400µ	+50% -20%	15V	Wima Printilyt
C69		5000µ	+50% -20%		Mullard C432 FR/E 5000
C70		Not Used			
C71		Not Used			
C72a		0.1µ	5%	150V	GEC Type PFT
C72b	1592Hz	0.033µ	5%	150V	" " "
C72b	1000Hz	0.25µ	5%	150V	" " "
C72c	1592Hz	Selected between 0.005 and 0.01µ		5% 150V	GEC Type PFT
C72c	1000Hz	Selected between 0.01 and 0.02µ		5% 150V	" " "
C73 C74 C75	1592Hz 1000Hz	6.28n 10n	1%	33V	GEC Type PF Waycom Type MIAL 613.2
C76	1592Hz 1000Hz	3.14n 5.0n	1%	33V	GEC Type PF Waycom Type MIAL 613.2
C77		100µ	+50% -20%	15V	Wima Printilyt
C78		250µ	+50% -20%	16V	Mullard Type C437/AR/250
C79		400µ	+50% -20%	15V	Wima Printilyt
C80		400µ	+50% -20%	15V	Wima Printilyt
C81		20µ		64V	Mullard C426/AR/H20
C82		20µ		64V	" " " "
C83		20µ		64V	" " " "
C84		0.7p-3.7p	Variable		Mullard C004 EA/3E
C85		0.7p-3.7p	Variable		" " " "
C200		100µ	+50% -20%	6V	Waycom Printilyt
C201		1000p	+50% -20%	150V	S. E. I. Type PFT
C202		Not Used			
C203		Not Used			
C204		500p	5%	125V	S. E. I. Type PFT
C205		47n	5%	100V	Wima Type MKS
C206		500µ		15V	Wima Printilyt
C207		50µ	+50% -20%	6V	Waycom Printilyt
C208		50µ	+50% -20%	6V	Waycom Printilyt

Cct. Ref.	Description	Style or Supplier and Type
C209	30p 2% 150V	GEC Type PF
C210	10n 5% 125V	S. E. I. Type PFT

Diodes

Cct. Ref	Type	Supplier
MR1	BYX10	Mullard
MR2	1S2051A	Texas
MR3	1S2039	Texas
MR4	OA200	Mullard
MR5	OA200	Mullard
MR6	OA200	Mullard
MR7	OA200	"
MR8	OA202	"
MR9	OA202	"
MR10	OA202	"
MR11	OA202	"
MR12	OA202	"
MR13	OA202	"
MR14	OA202	"
MR15	OA202	"
MR16	1S020	Texas
MR17	1S020	"
MR18	1S020	"
MR19	1S020	"
MR20	1S2039	"
MR21	OA200	"
MR22	Not Used	
MR23	OA200	Mullard
MR24	OA200	"
MR25	OA200	"
MR26	OA200	"
MR100	BAX13	"

Transistors

Cct. Ref	Type	Supplier
VT1	BC109	Mullard
VT2	BC109	"
VT3	BC109	"
VT4	BC109	"
VT5	BC109	"
VT6	BC109	"
VT7	BC109	"
VT8	BC109	"
VT9	BC109	"
VT10	BC109	"

Cct. Ref.	Type	Supplier
VT11	BC109	Mullard
VT12	BC109	"
VT13	BC109	"
VT14	BC109	"
VT15	Not Used	
VT16	Not Used	
VT17	BC109	"
VT18	BC109	"
VT19	Not Used	
VT20	Not Used	
VT21	40319	R.C.A. (or Mullard BCY32)
VT22	BC109	Mullard
VT23	BC109	" (Selected for β of 70 to 120 at I_c 10mA)
VT24	BCY70	R.C.A. (or Mullard BCY32)
VT25	2N3053	"
VT26	BC109	Mullard
VT27	BC109	"
VT28	BC109	"
VT29	BC109	"

Miscellaneous

TH1		R14	S.T.C. Thermistor
N1-N4 N8-N11		3L	Hivac Neon Lamp
N5-N7		GL12	Philips Neon Lamp
V1-V8		GR10M GN4	Ericsson Alternatives. STC Digital Indicator Tubes
IC1		SL702C	Plessey
IC2		SL702C	"
FS1		250mA 'Slow Blow'	Beswick Type TDC134
M1-M2	centre zero	100-0-100μA FSD	S Weston S819
	L.H. zero	10-0-100μA FSD	" "

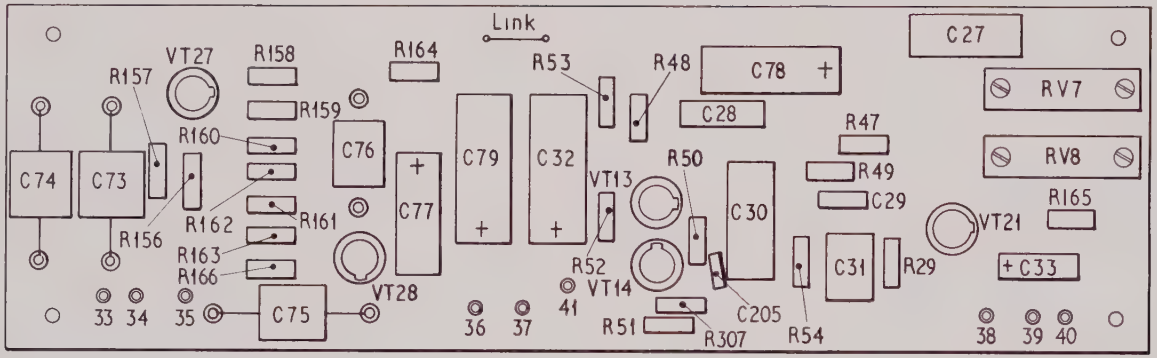


Fig.22 Bandpass and 90° Phase Shift Component Assembly

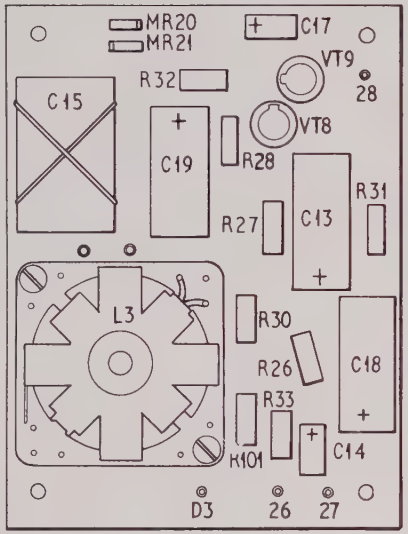


Fig.23 Inductor Board L3 Component Assembly

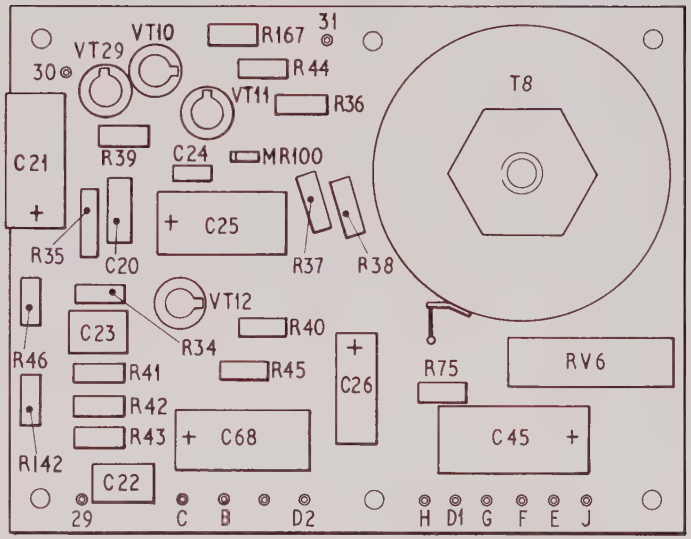


Fig.24 Feedback Amplifier Component Assembly

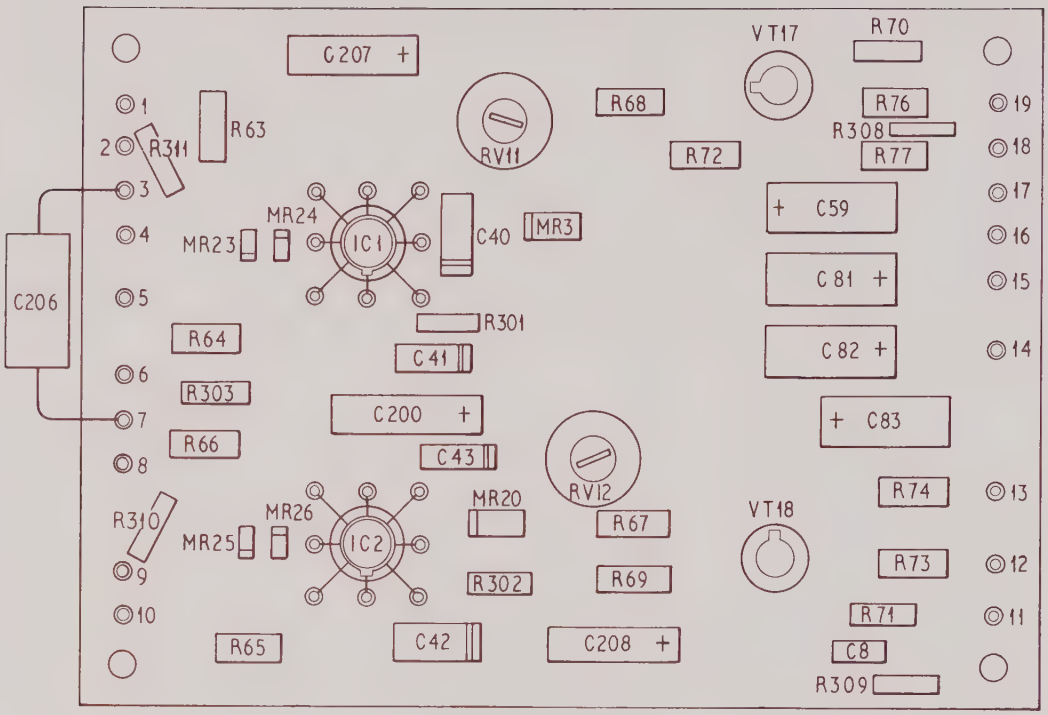
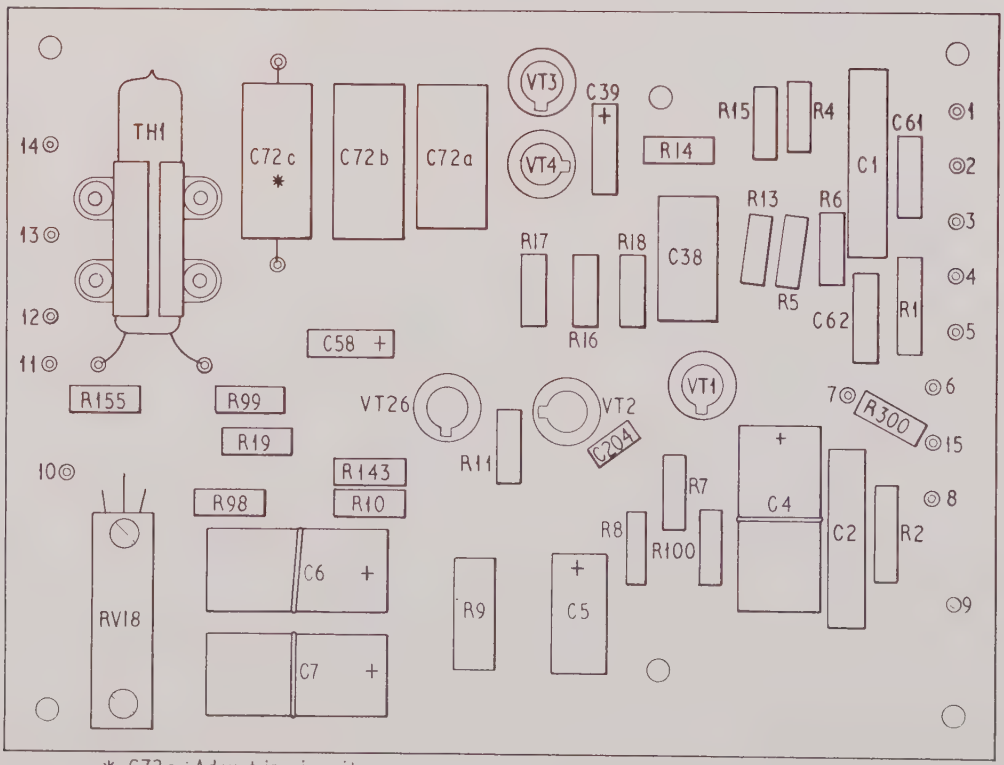
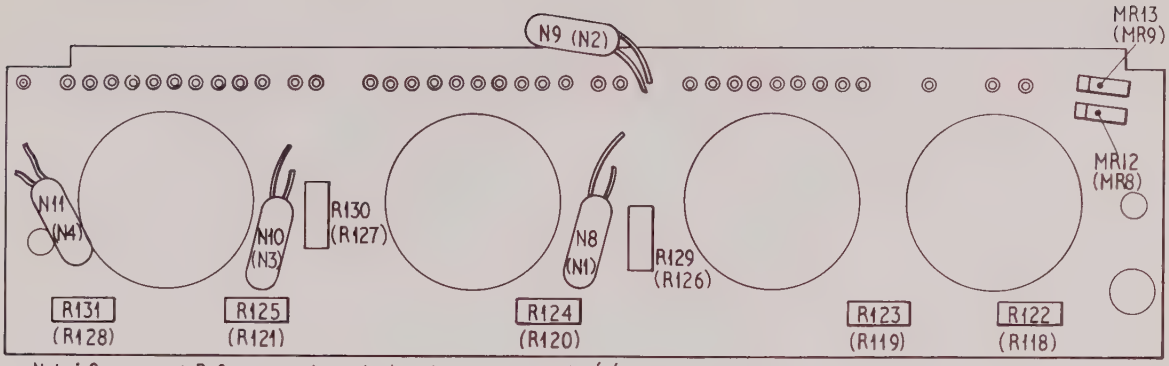


Fig.25 Squarewave Generator & Phase Sensitive Detectors Component Assembly



* C72c : Adjust in circuit

Fig.26 Oscillator Printed Circuit Component Assembly



Note: Component References shown in brackets refer to the 'C' Counter Tube Assembly

Fig.27 C&G Decimal Point Indicators Component Assembly

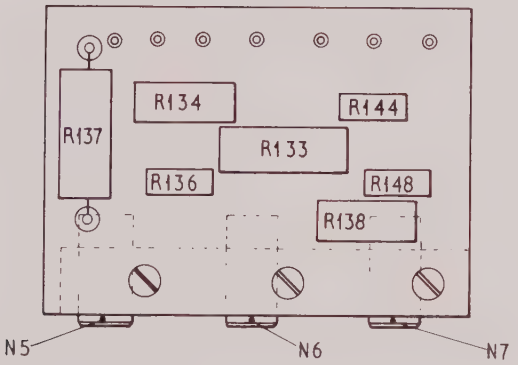


Fig.28 'C' Sequence Indicators Component Assembly

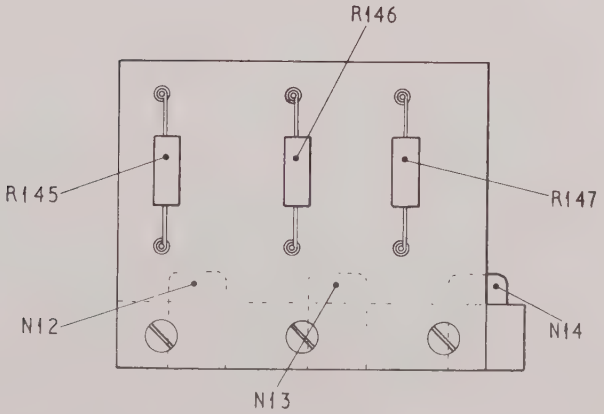


Fig.29 'G' Sequence Indicators Component Assembly

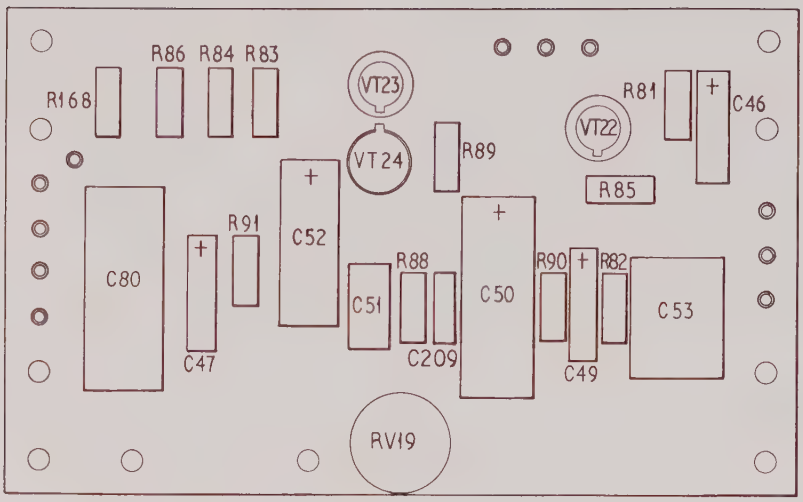


Fig.30 Lead Eliminator Printed Circuit Component Assembly

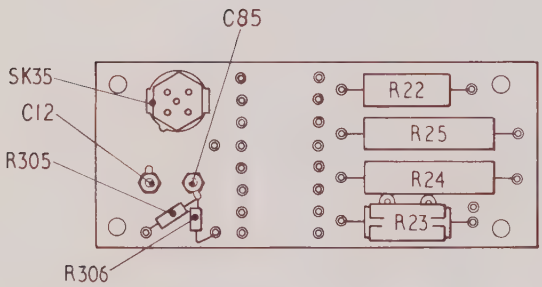


Fig.31a Standards Board Component Assembly (Early version)

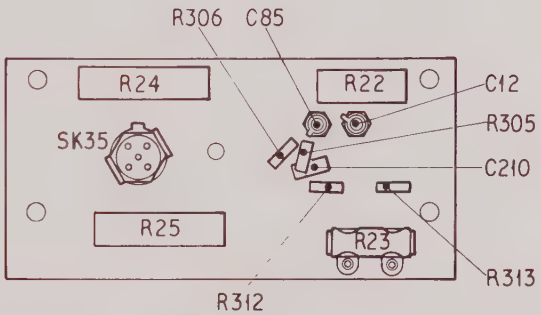


Fig.31b Standards Board Component Assembly (Later version)

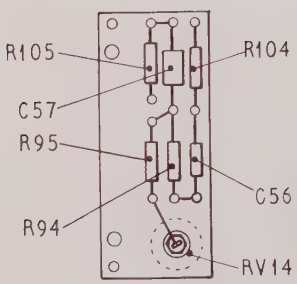


Fig.32 Reset Circuit Component Assembly

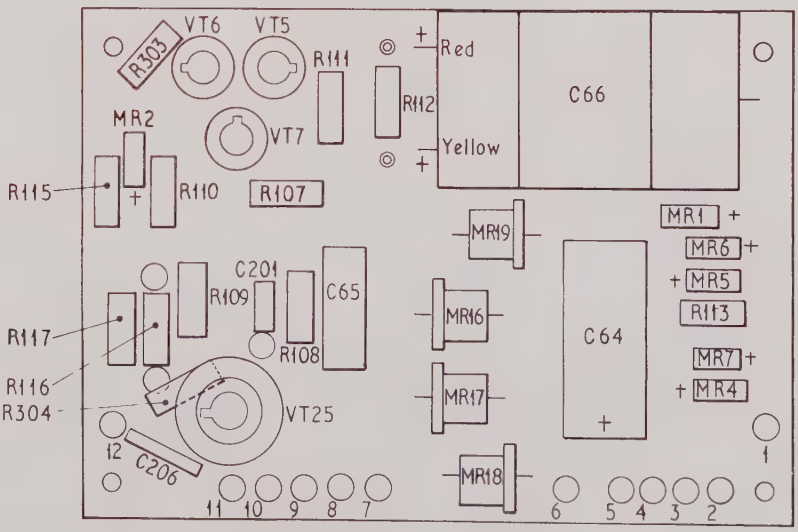


Fig.33 Power Supply Board Component Assembly

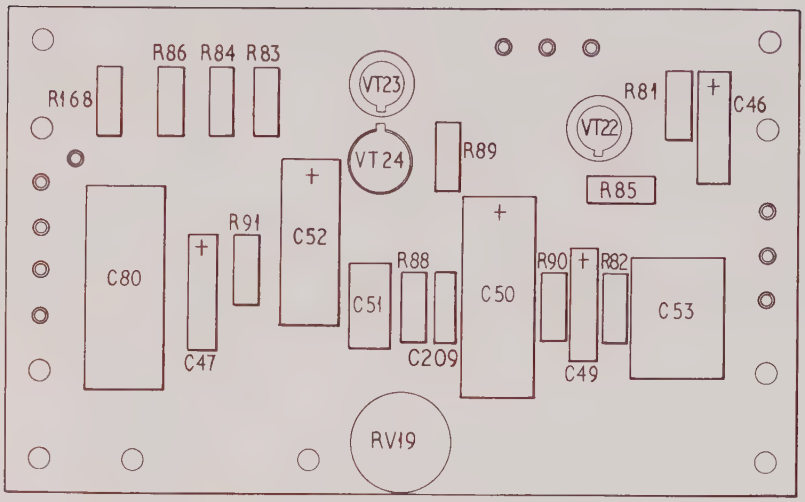


Fig.30 Lead Eliminator Printed Circuit Component Assembly

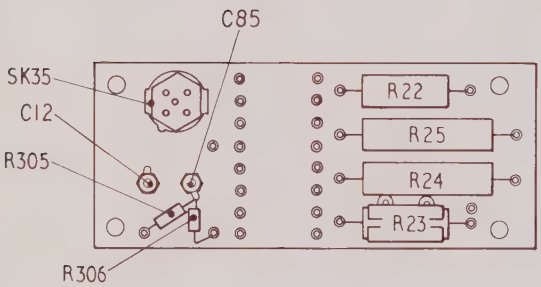


Fig.31a Standards Board Component Assembly (Early version)

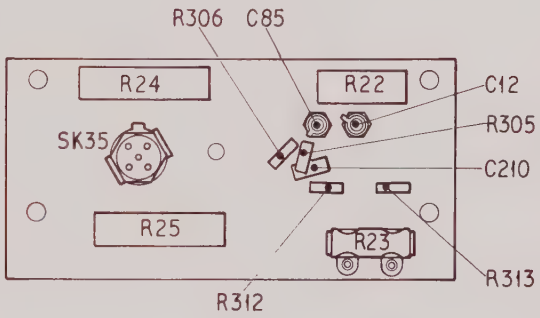


Fig.31b Standards Board Component Assembly (Later version)

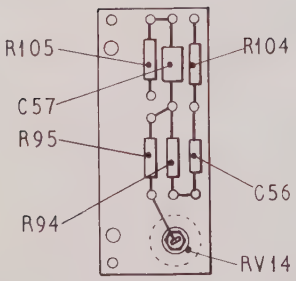


Fig.32 Reset Circuit Component Assembly

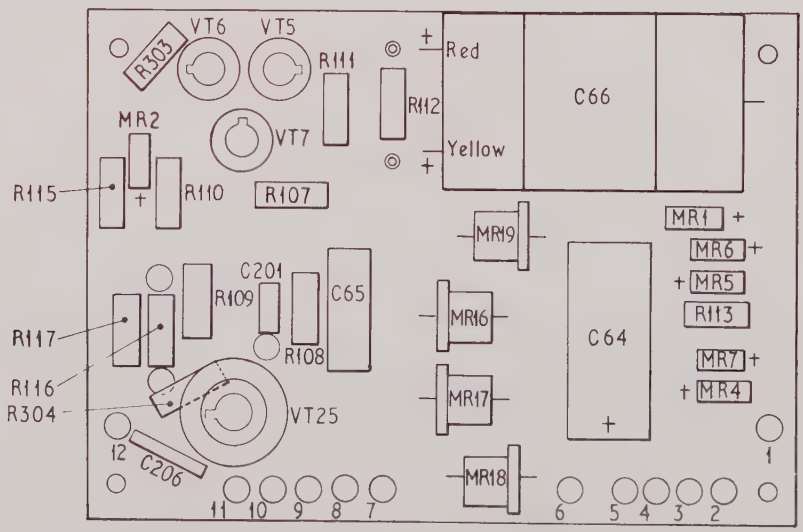
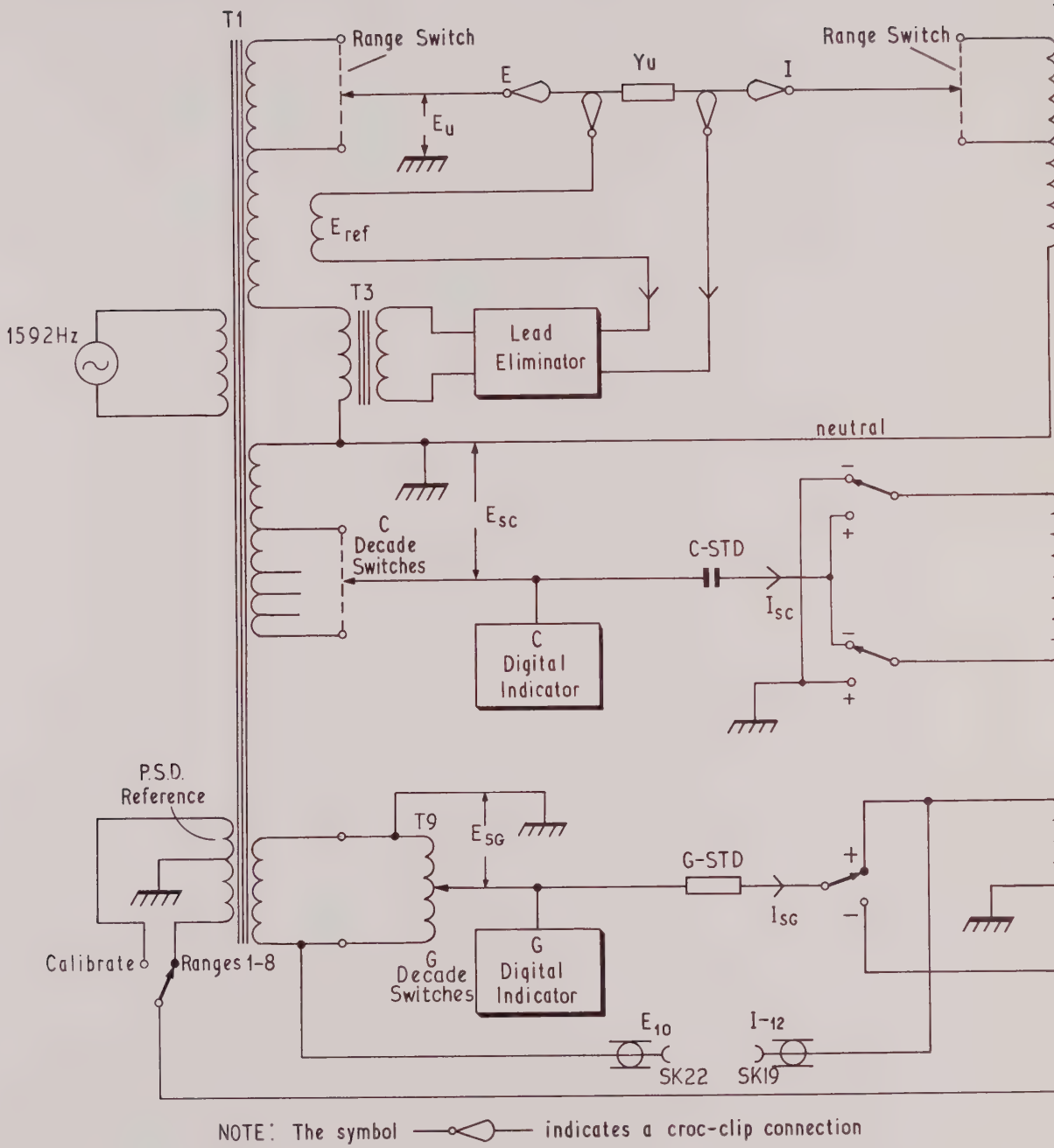


Fig.33 Power Supply Board Component Assembly

| | | |

| | | |



NOTE: The symbol —◁— indicates a croc-clip connection

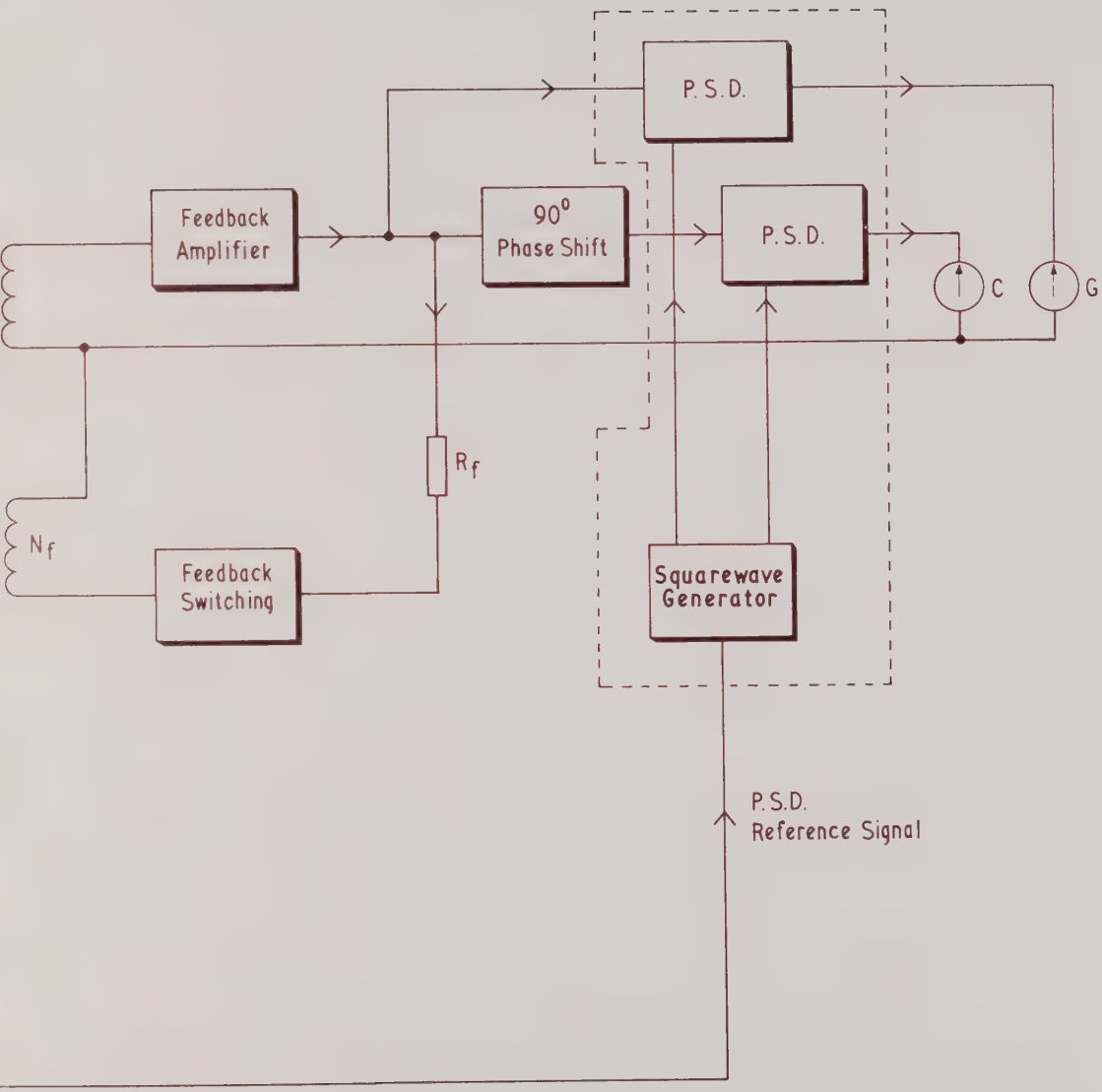
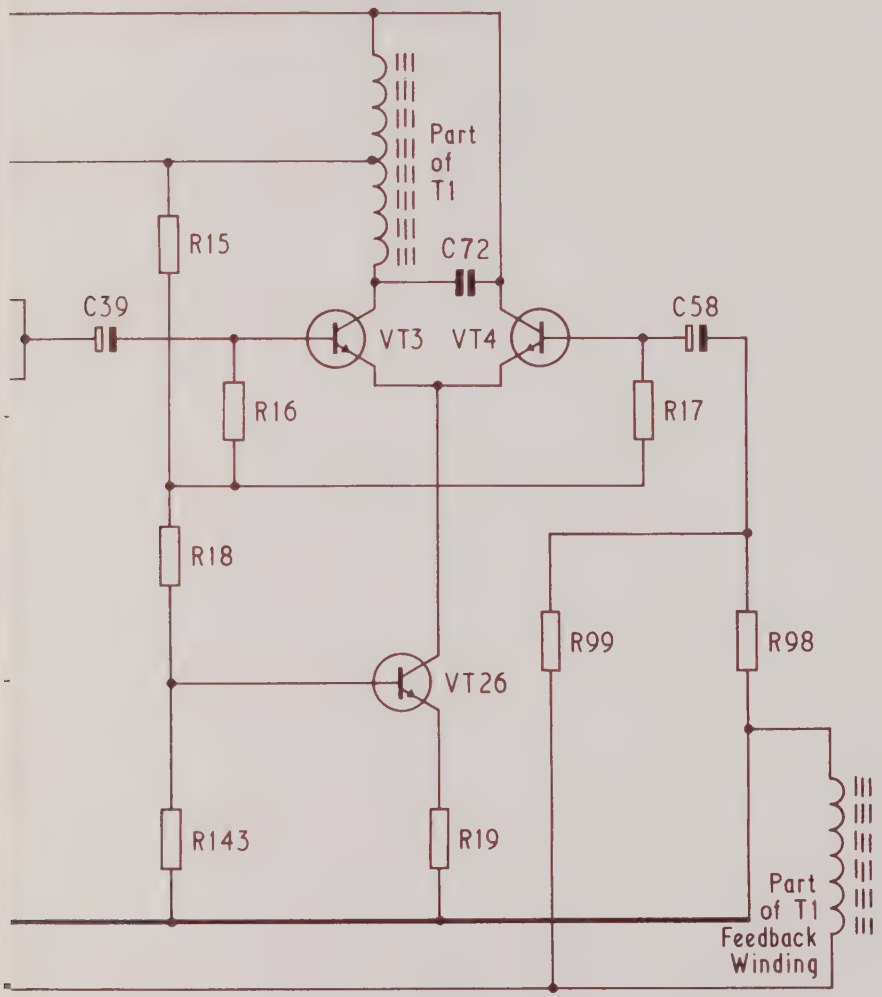


Fig. 2 B331 Block Schematic Diagram

| | | |

15 18 143 16 19 99 17 98	R
39 72 58	C
VT3 T1 VT26 VT4	Misc.



mplified Circuit Diagram of the Oscillator

B33INK II
D13905 C

| | | |

12	13,11,10		14,155		15,18,143	19	16,17	98		99				R
D4		6	38	7	39			58			72a,b,c			C
	VT2		TH1		RV18		VT26	VT3,VT4				PL9	PL9	T1	Misc.

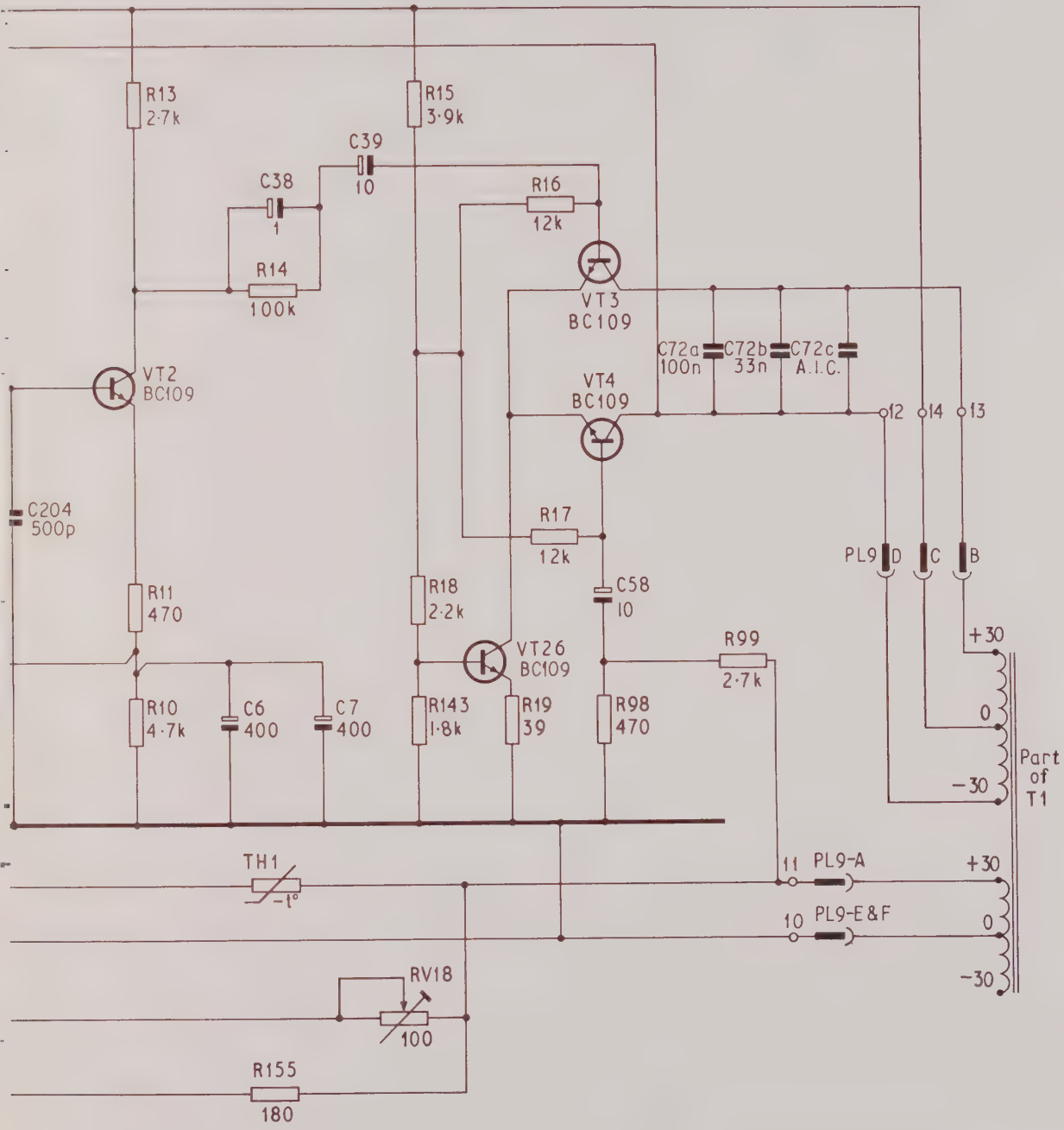


Fig.4b Oscillator Circuit B33I MKII D13905C

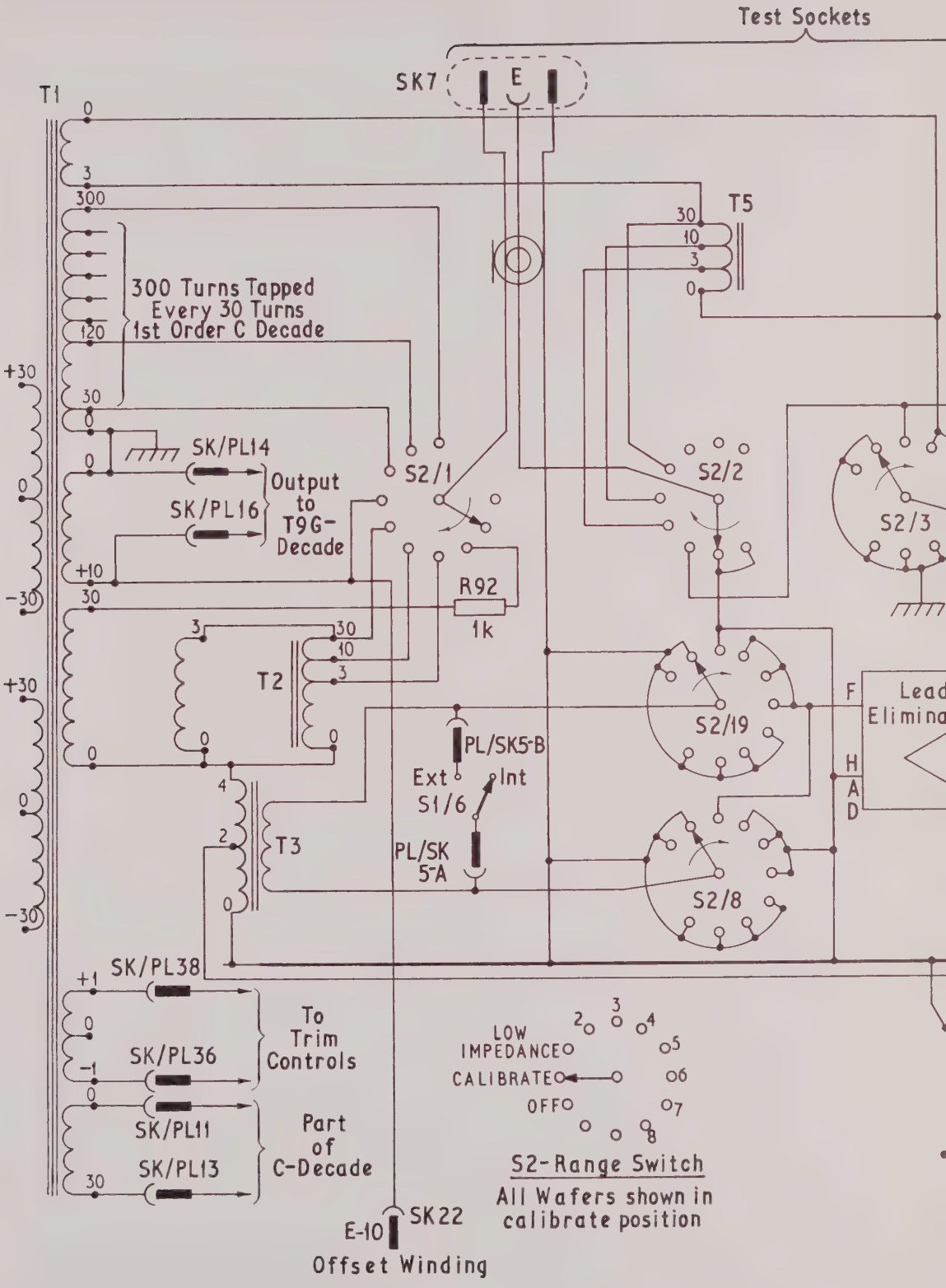
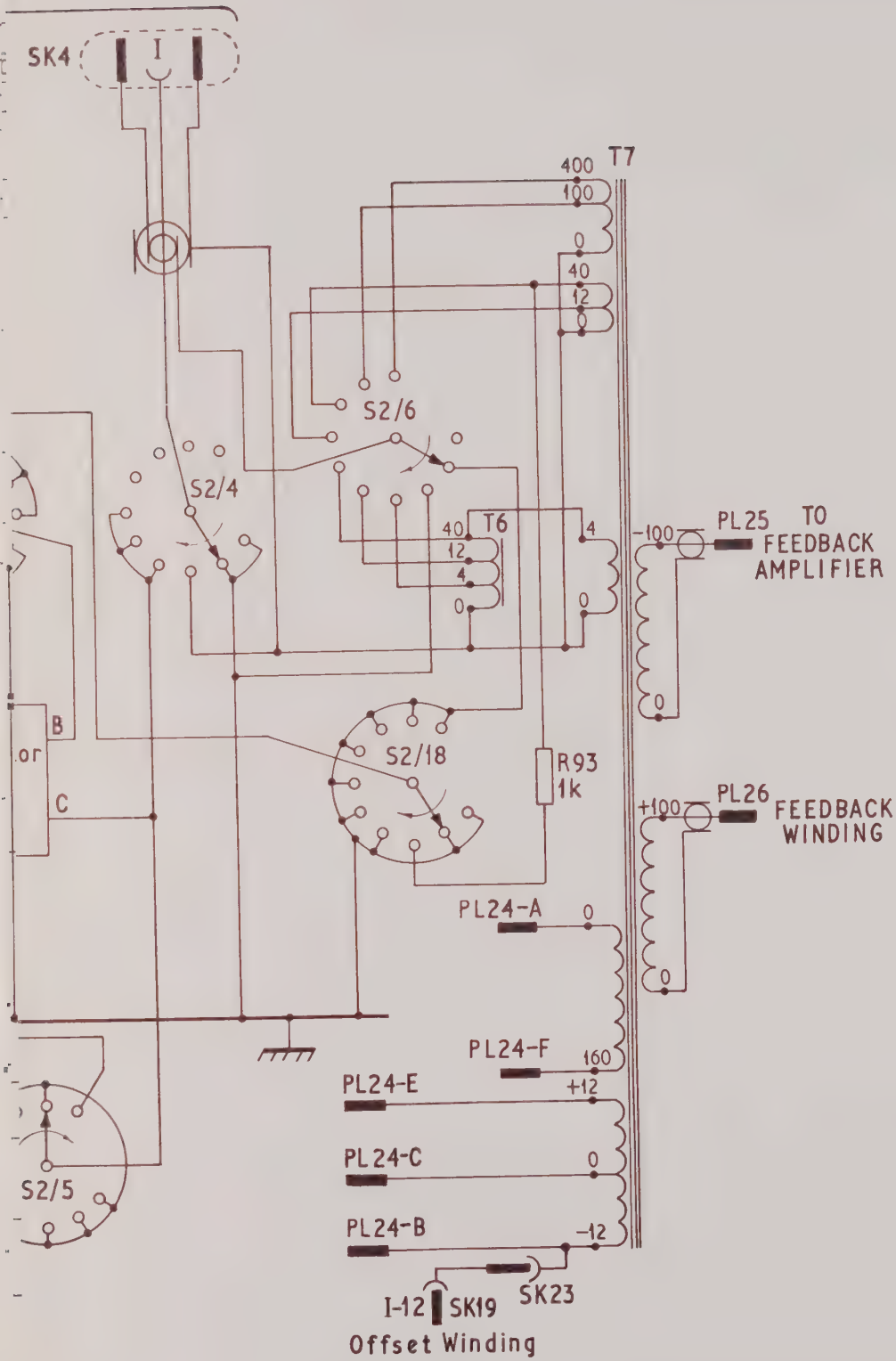
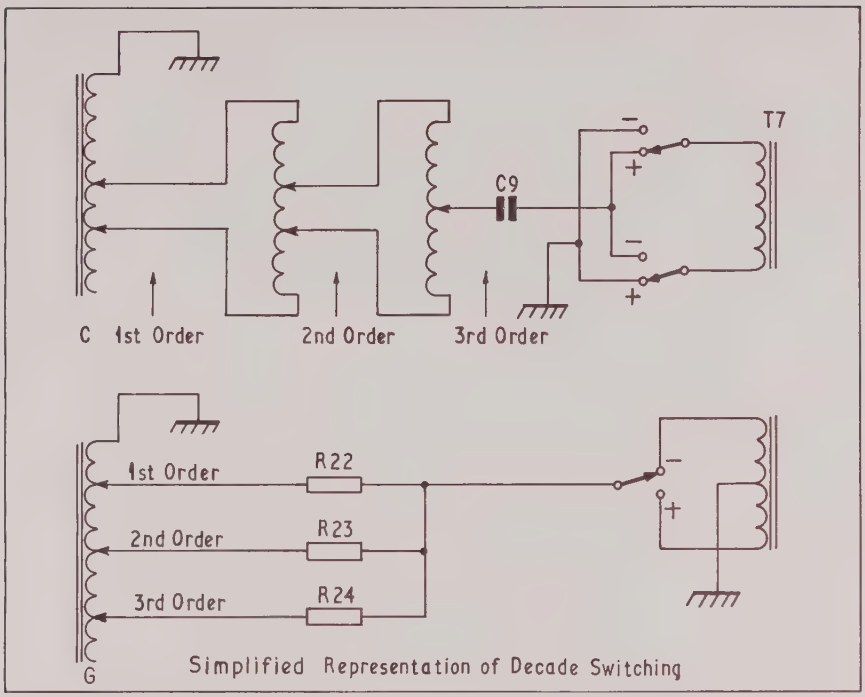


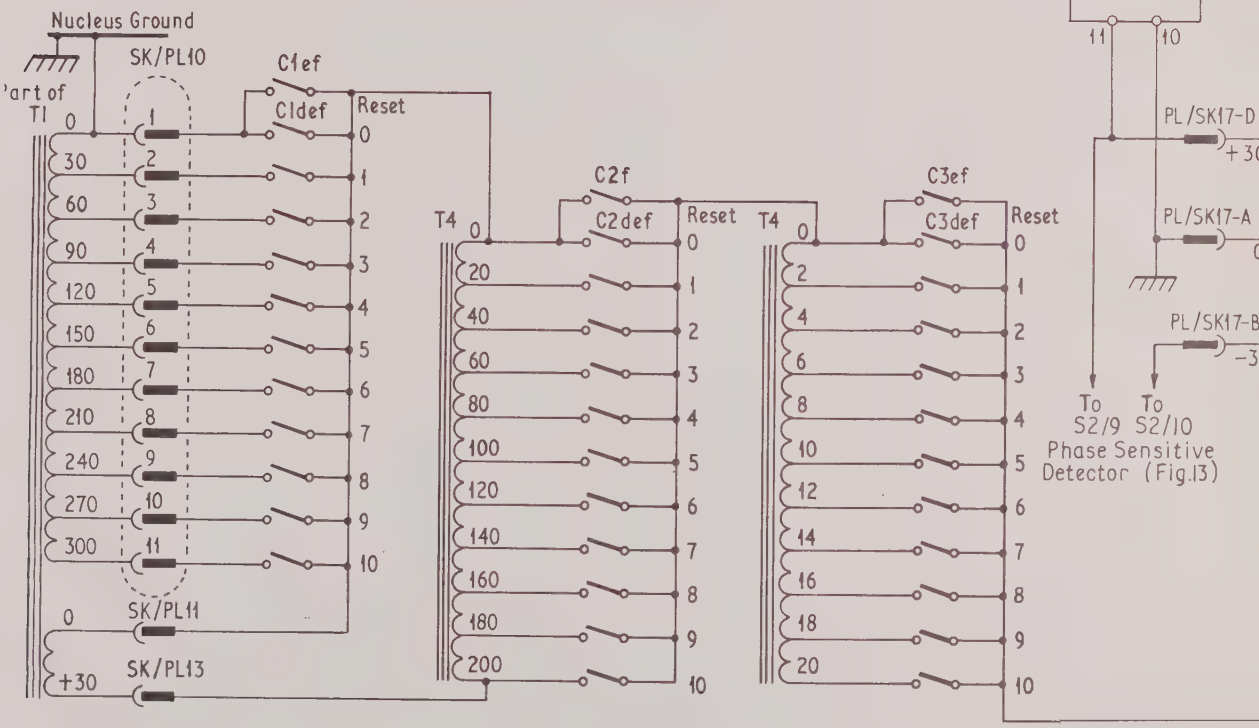
Fig.5 B331 Nucleus Circuit 13



B331 MK II
D13901 D



Simplified Representation of Decade Switching



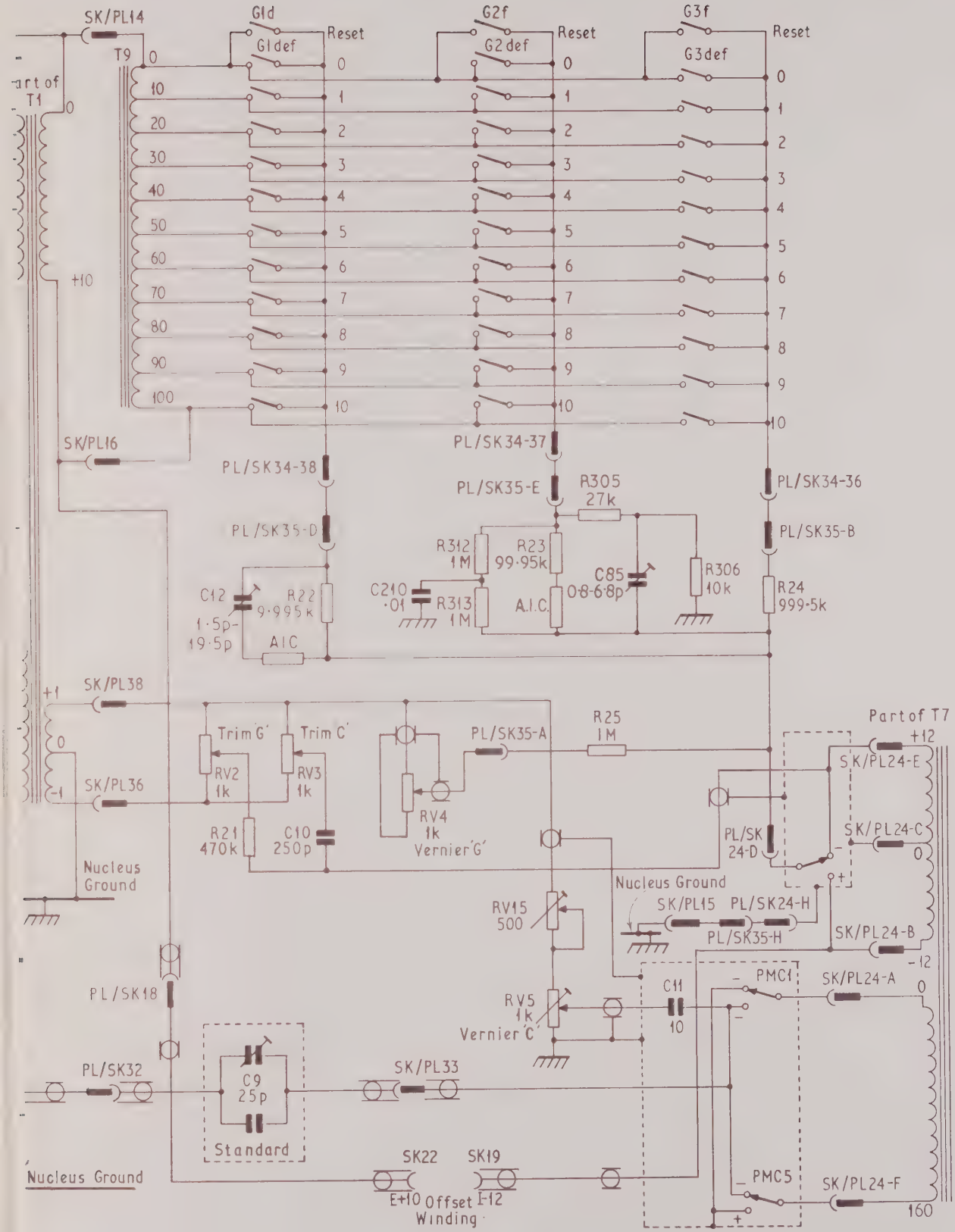


Fig.8 C&G Decade Switching & Standards Circuit

8331 MKII
D139010

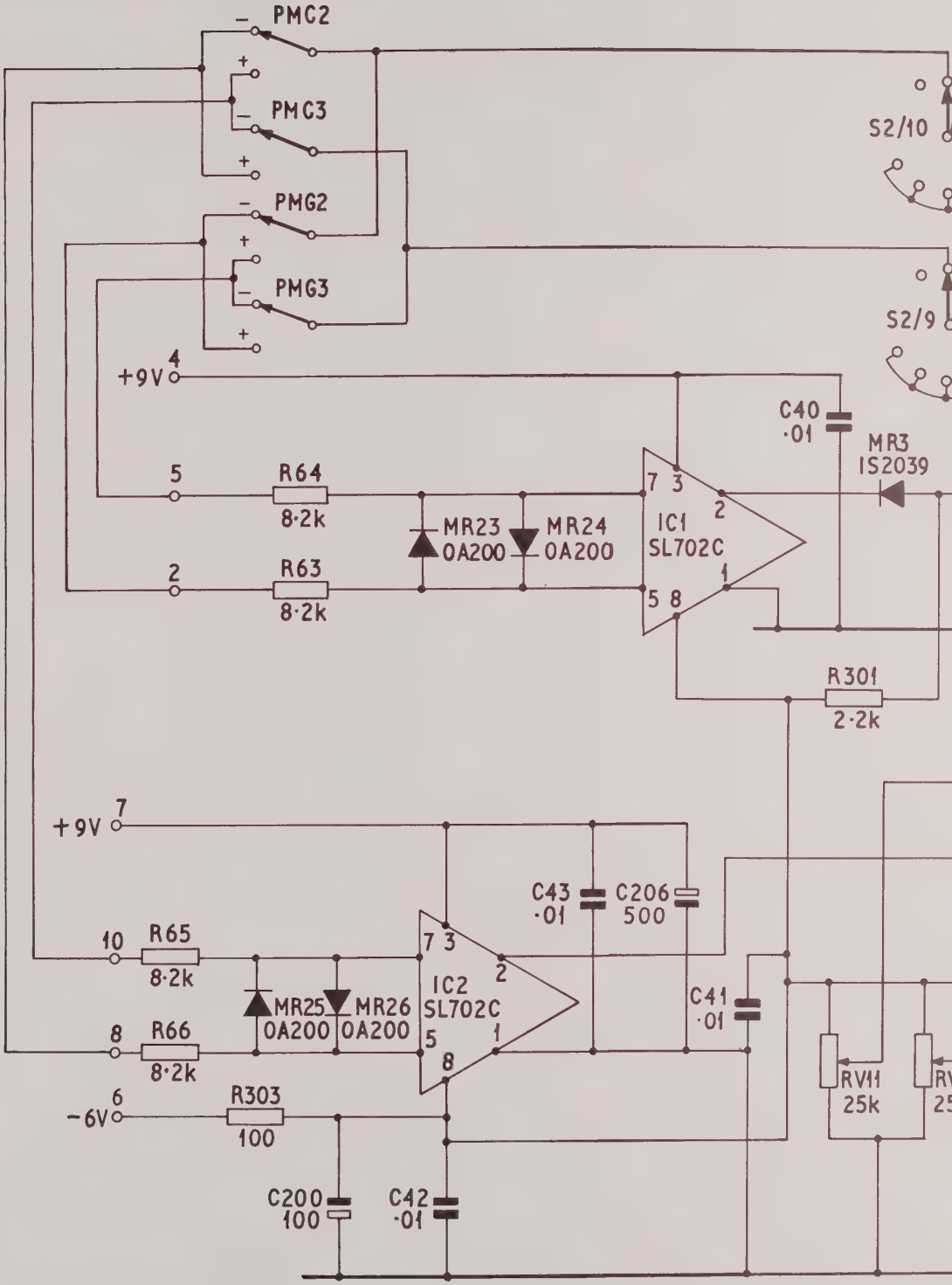
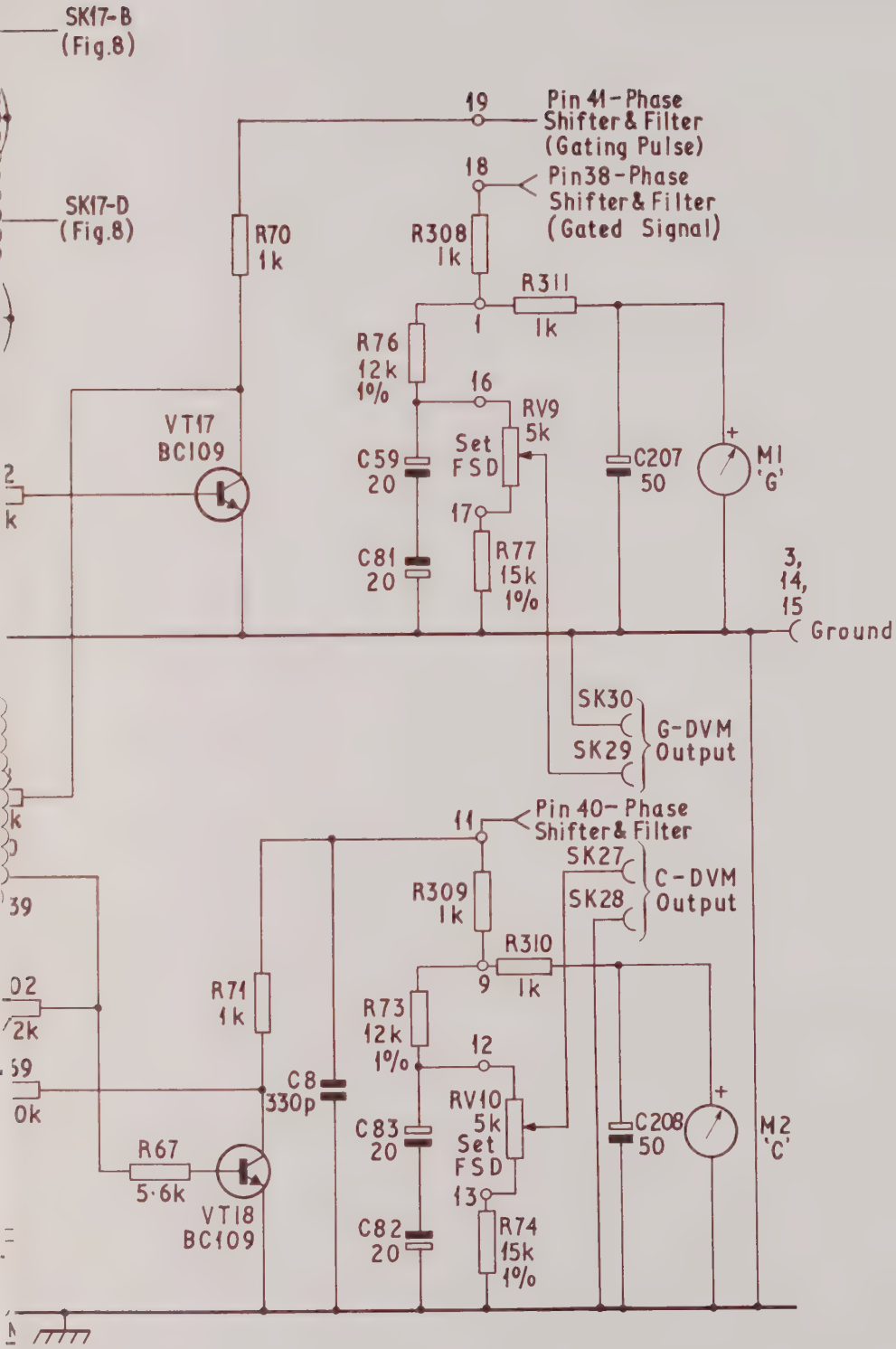


Fig.13 Squarewave Generator



ase Sensitive Detector Circuit

B331MKII
D13909E

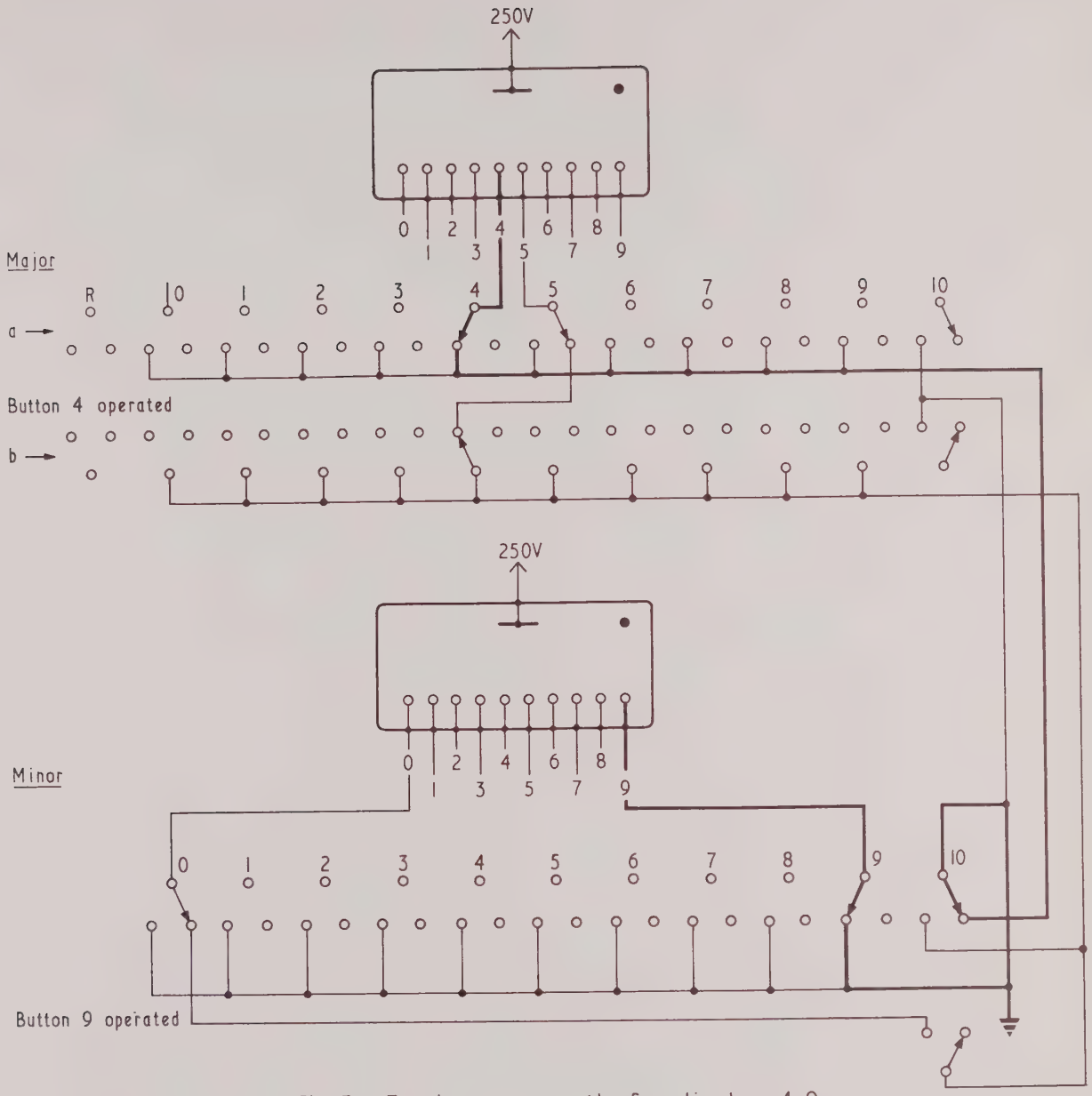


Fig.15a Earth return path for display 4·9

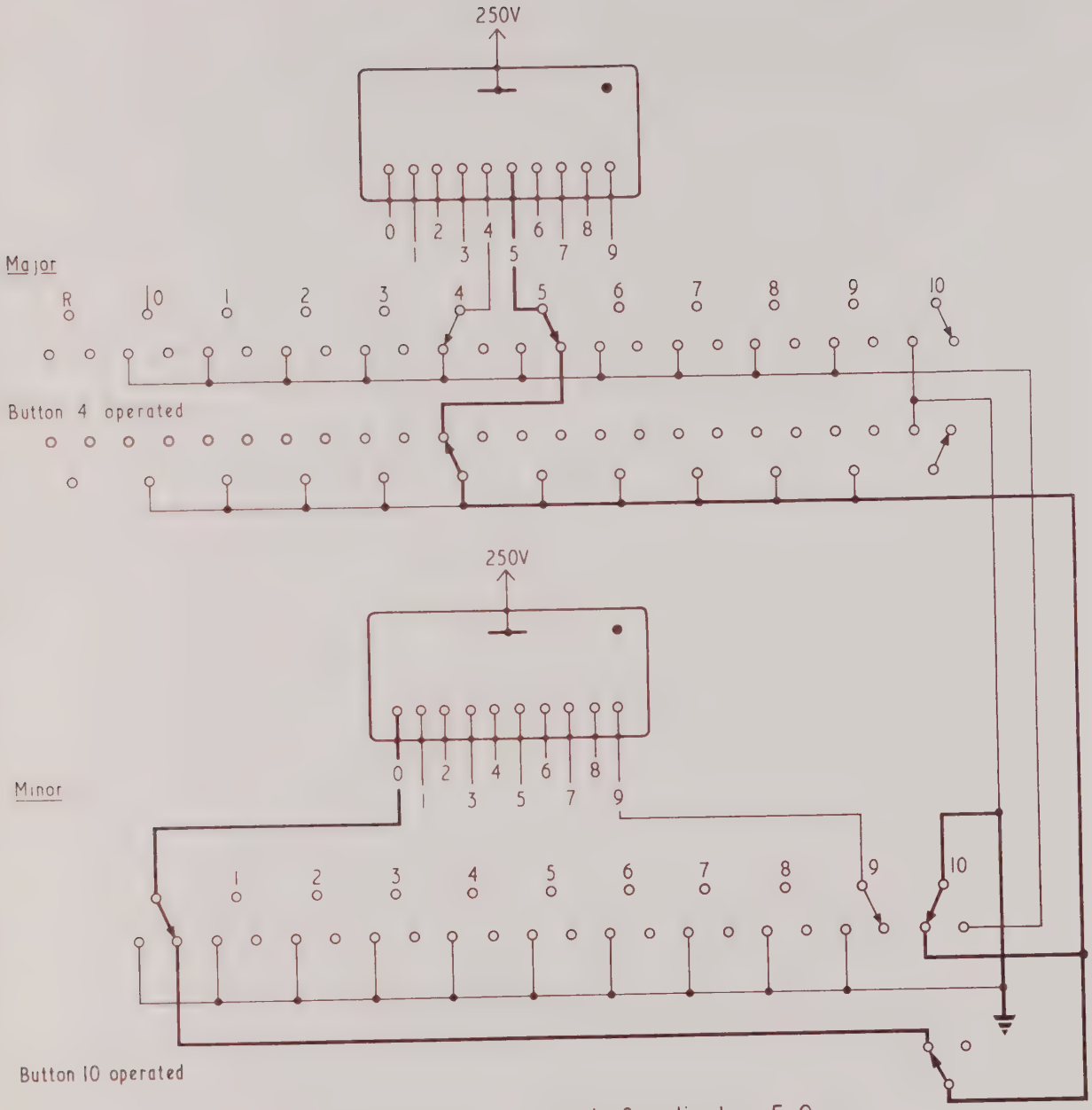
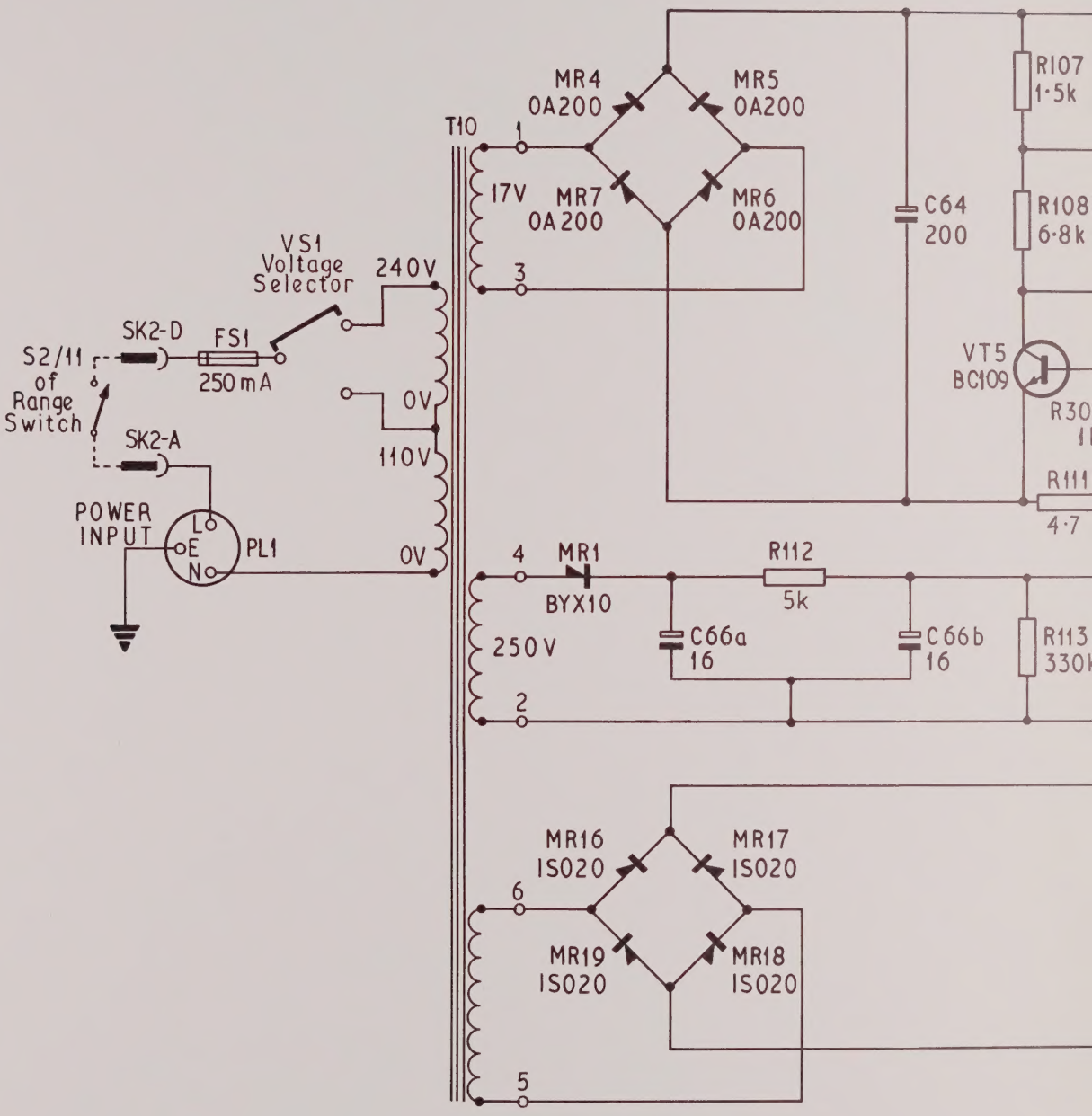


Fig.15b Earth return path for display 5·0 when buttons 4·10 are operated

Fig.15 Simplified Diagram of Digital Indicator Switching


T10
MR4
0A200
MR5
0A200
MR7
0A200
MR6
0A200
17V
1
3
VS1
Voltage
Selector
240V
0V
110V
0V
SK2-D
FS1
250mA
S2/11
of
Range
Switch
SK2-A
POWER
INPUT
L
E
N
PL1
C64
200
R107
1·5k
R108
6·8k
VT5
BC109
R111
4·7
4
MR1
BYX10
R112
5k
250V
C66a
16
C66b
16
2
MR16
IS020
MR17
IS020
6
MR19
IS020
MR18
IS020
5

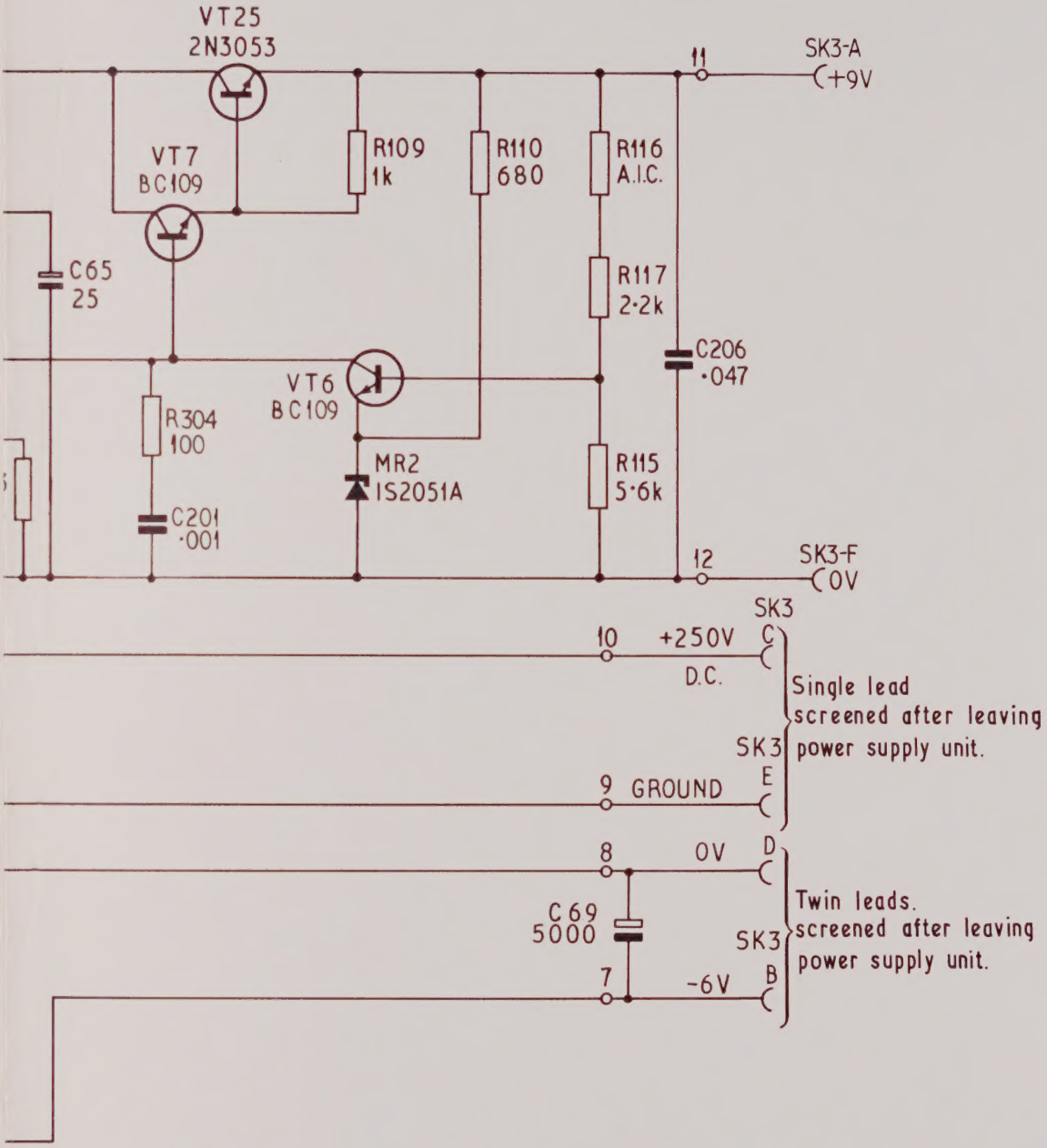


Fig. 20 Power Supply Circuit B331MKII D13902C

MP MASTER
MA24502

THE WAYNE KERR COMPANY LIMITED

WAYNE KERR, NEW MALDEN,

Telex: 262333 Telephone: 01

eeden Electronics Limite
rsted, Bognor Regis, West Sussex, PO22 9RL
(02433) 25811 Telex: 86881
APH • RENDAR • WAYNE KERR

Printed in England JP/11/69/500